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Sacramento and San Joaquin River Basins

Comprehensive Study

# Lower San Joaquin River Assessment

US Army Corps of Engineers
Sacramento District

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# INTRODUCTION

## BACKGROUND

In response to recurring flooding in California's Central Valley, Congress directed the Army Corps of Engineers (Corps) to conduct a comprehensive study of flood damage reduction and environmental restoration in the Sacramento and San Joaquin River Basins. Similarly, the Governor of California established a Flood Emergency Action Team (FEAT) to assess and report on the flood damage. The FEAT's recommendations resulted in The State Reclamation Board (State) partnering with the Corps' Sacramento District to form the Sacramento and San Joaquin River Basins Comprehensive Study Team.

The San Joaquin River levee system was originally designed to convey both rainfall and snowmelt events. Reservoirs constructed on major tributaries were designed primarily to manage the substantial precipitation events that are common in the San Joaquin River Basin. Although the most frequent source of flooding in the San Joaquin River Basin is due to snowmelt, substantial flooding can also result from rain. In addition, the flow carrying capacity of the system has diminished over time. Several factors that have contributed to diminishing flood flow capacity include increased sedimentation and localized channel "choke points."

The construction and continued operation and maintenance of the network of flood management facilities have greatly contributed to the degradation of the environment. Confining flood flows in reservoirs and between levees has caused the loss of natural hydrologic and geomorphic processes. Habitat for fish and wildlife has been lost or severely degraded as a result of the loss of natural processes. Mitigation for this lost habitat has been inadequate and much of the remaining areas of habitat are of insufficient size to support healthy native plant and animal communities.

As part of the Comprehensive Study, potential flood damage reduction and ecosystem restoration opportunities for the full length of the San Joaquin River and major tributaries will need to be assessed. However, it is believed that one area requiring a current focused analysis is the reach of the lower San Joaquin River and its distributaries downstream from its confluence with the Stanislaus River. Potential actions in this area could be influenced by potential system modifications in upstream reaches of the San Joaquin River. Potential actions along this reach of river could also affect water stages and flood conditions further downstream in the central and western Delta. In addition, this interface area between river flow and tidal action will require hydraulic analysis somewhat different than used on the other reaches of the San Joaquin River by the Comprehensive Study to date.

Levees have been constructed throughout the Delta and upstream on the San Joaquin River. The federally authorized and constructed portions of the levees and appurtenant structures in this area consists of about 100 miles of intermittent levees along the San Joaquin River, Paradise Cut, Old River and the lower reaches of the Stanislaus River. In addition, the Lower San Joaquin River and Tributaries Project is an intricate series of minor levees and channel modifications that have been constructed in the study are. These are currently owned, operated and maintained by local interests throughout the river system.

## PURPOSE AND SCOPE

This study focuses on the San Joaquin River downstream from its confluence with the Stanislaus River (RM 75) to the Delta. Along the San Joaquin River, this could extend into the Stockton Deep Water Ship Channel at RM 40. Because of the complex system of levees and channel improvements in the area, this scope also includes waterways within the Delta that could be hydraulically influenced by efforts upstream along the San Joaquin River, including Paradise Cut, Old River and Middle River.

The objectives of this study are:

- To identify and evaluate hydrodynamic conditions, flow/stage frequency relationships, and sediment transport relationships of the San Joaquin River and its distributaries from within the primarily study area extending from the confluence with the Stanislaus River down into portion of the Sacramento-San Joaquin Delta (Delta).
- To identify measures and alternative scenarios that can reduce flood stages and mitigate for and/or reduce damages within the study area and to restore ecosystem values within this area.

This report is organized into several chapters that address the objectives of this study:

- Chapter II provides a general overview of the lower San Joaquin River study area,
- Chapter III describes the hydrodynamic modeling tools used in this study,
- Chapter IV identifies fundamental flood problems in the area,
- Chapter V evaluates potential flood damage reduction and ecosystem restoration measures and scenarios, and
- Chapter VI summarizes the findings and conclusions drawn by this study.

## STUDY AREA LOCATION AND DESCRIPTION

The study area generally extends from Vernalis (downstream from the Stanislaus confluence) to the southern Delta. As described in *Existing Hydrodynamic Conditions in the Delta During Floods* (COE, 2001), the hydrodynamics of the Delta are complex and simultaneously influenced by the inflows from the Sacramento and San Joaquin rivers, eastside streams, and tidal currents. Unlike other reaches of the Comprehensive Study, stage peak and flow peak do not necessarily occur at the same time in the Delta. Alternative directions of flow are common within a day in Delta waterways. Thus, although a gross agreement may be reached on the downstream boundary in the south Delta, to which the hydraulic influence of the San Joaquin River ceases, a definite location cannot be defined unless other contributing factors were properly defined.

The south Delta is both modeled by SJRUNET and the Delta Simulation Model II (DSM2) developed by the California Department of Water Resources (DWR). However, DSM2 is limited in simulating levee failures in flooding conditions and floodwater hydrodynamics around bridges and other obstacles in the river. Therefore, the DSM2 modeling area was reduced and used jointly with SJRUNET to evaluate the hydrodynamic condition in the Delta. The potential measures to reduce flood damage in the south Delta were evaluated by SJRUNET, and DSM2 was used to evaluate the resulting impacts in the remaining Delta. Note that, the results of DSM2 should be used in scenario comparison only due to its limitations in simulating levee failures. No specific indications of levee safety or required levee height can be derived from DSM2 results. See *Existing Hydrodynamic Conditions in the Delta During Floods* (COE, 2001) for more details.

In conclusion, the study area of the lower San Joaquin River Assessment was determined mainly by the modeling boundary of SJRUNET. The downstream boundary is generally delineated by the following locations: the confluence of San Joaquin River and Stanislaus River, San Joaquin River near Stockton, Middle River near Victoria Canal, Old River near Tracy Boulevard, and Grant Line Canal near Tracy Boulevard. Historical records in the 1997 flood support the assumption that water stages below these locations are largely influenced by the factors other than San Joaquin River flow.

# CHAPTER II

# OVERVIEW OF THE SAN JOAQUIN WATERSHED

## BACKGROUND

The San Joaquin River Basin covers approximately 13,500 square miles, extending about 120 miles from the northern to southern boundaries. The total watershed area is over 16,700 square miles, including drainage from the Central Sierra rivers and streams and the central Delta islands. The basin lies between the crests of the Sierra Nevada on the east and the Coastal Range on the west, and extends from the northern boundary of the Tulare Lake basin near Fresno to the confluence with the Sacramento River in the Sacramento-San Joaquin Delta.

Major tributaries to the San Joaquin River include the Cosumnes, Mokelumne, Calaveras, Stanislaus, Tuolumne, and Merced Rivers. These streams, in combination with the San Joaquin River, contribute the major portion of the surface inflow to the basin. Minor streams on the east side of the valley include the Fresno and Chowchilla Rivers, and Burns, Bear, Owens, and Mariposa Creeks. Panoche, Little Panoche, Los Banos, San Luis, Orestimba, and Del Puerto Creeks comprise the minor streams on the west side. The west side streams contribute relatively little runoff compared with the larger, eastside tributaries. Numerous other small foothill channels carry water only during intense storms.

The San Joaquin River Basin and the Tulare Lake Basin are hydrologically connected through the Kings River. During high runoff periods, the James Bypass, a distributary channel of the Kings River, discharges water into the San Joaquin River near Mendota. In addition, floodwater is diverted to the San Joaquin River from Big Dry Creek Reservoir near Fresno. Flows from the rivers and creeks are significantly reduced by storage, diversions, and channel seepage losses as they cross the valley floor such that only a portion of the water at the foothill line reaches the San Joaquin River. The historic channel of the San Joaquin River carries little water during the summer months.

Flood control facilities in the San Joaquin River Basin consist of a complicated, interconnected series of natural, semi-modified, and constructed channels, with and without levees. In addition, a number of canals have been constructed throughout the valley with the primary function of water supply, but these canals may also be used for diverting and/or controlling flood runoff. Along the eastside of the valley, multipurpose reservoirs are located primarily in the foothills and provide various levels of flood protection.

The flood management system includes levees along the lower portions of Ash and Berenda sloughs; Bear Creek; Fresno, Stanislaus, and Calaveras Rivers; and various leveed sections along the San Joaquin River. Major bypass systems in the San Joaquin River system include the Chowchilla, Eastside, and Mariposa Bypasses, which intercept and divert water from the San Joaquin River and many of its tributaries. The capacity of the San Joaquin River generally decreases moving downstream between Friant Dam and the Mariposa Bypass.

The Mokelumne, Cosumnes, and Calaveras Rivers are not included in the hydraulic modeling or data collection efforts for this study. These watercourses drain directly to the Delta and are treated as separable from the Sacramento and San Joaquin River systems. In addition, other major studies or projects are ongoing for both the Cosumnes and Calaveras Rivers.

Several items are reviewed in this Chapter:

- Sediment analysis of the San Joaquin River and Tributaries
- Flow splits of San Joaquin River in the Delta waterways
- Tidal influence in the Delta
- Existing projects and programs that influences flow dynamics in the study area, and
- Future projects or programs that could influence flow dynamics in the study area.

## SEDIMENT ANALYSIS OF THE SAN JOAQUIN RIVER AND TRIBUTARIES

### Recent Geomorphic and Sediment Transport Studies

A basic understanding of the geomorphology and sediment dynamics of the Sacramento and San Joaquin River basin systems is required to develop a comprehensive flood management master plan. *Geomorphic and Sediment Baseline Evaluation of the San Joaquin River from the Delta to the Confluence with the Merced River and Major Tributaries* (Mussetter Engineering, Inc., April 2000; April 2000 Report) documents the recent reconnaissance-level geomorphic and sediment transport studies on the San Joaquin River. The study focuses on the San Joaquin River between Old River (RM 54) and the confluence with the Merced River at Hills Ferry (RM 118). That report, hereafter referred to as the April 2000 Report, and other data were reviewed and analyzed as part of a subsequent effort to assess sediment movement, accumulation, and erosion under the above mentioned flood flow conditions. This section documents the findings from both the April 2000 report and subsequent efforts, including data collection and thalweg analyses.

#### *Historic Data*

Historical information describing the characteristics of the San Joaquin River includes:

- Historical maps of the system prior to significant man-made interventions (Hall, 1887)
- A hydrographic survey of the San Joaquin River conducted by the California Debris Commission (CDC) in 1914 and later updated in 1930 by DWR
- Levee profiles and 1951 low water channel measurements (thalweg) of the San Joaquin River and tributaries developed by the Corps (COE, 1955)
- A repeat survey of some of the 1914 hydrographic survey by the U.S. Geologic Survey (Simpson and Boldgett, 1974)
- Geological maps showing surface and subsurface geology of the valley (Marchandt and Allwardt, 1978; Bartow, 1985)
- Cross-sections of the San Joaquin River surveyed by DWR in 1983

- A topographic and hydrographic survey of the San Joaquin River and the lower reaches of the major tributaries by the Corps (COE) in 1998.

Data and information on the major tributaries are somewhat limited. The April 2000 Report relied upon bridge plans and bridge inspection reports obtained from California Department of Transportation (CALTRANS) to evaluate the aggradational or degradational status of the tributaries.

#### *Field Data Collection*

During the course of the April 2000 Report field reconnaissance of the lower San Joaquin River, bed material samples were collected for subsequent laboratory determination of their gradations. A single bed material sample was also collected along the lower reaches of the Stanislaus, Tuolumne, and Merced Rivers.

Two samples collected from the San Joaquin River downstream from the confluence with the Stanislaus River (Subreach 1) and one sample collected upstream from the confluence with the Stanislaus have almost identical $D_{50}$ values (median size of sampled materials). The Stanislaus River sample has a larger $D_{50}$ value, suggesting that the Stanislaus River has little effect on the bed material gradation of the San Joaquin River. It is presumed that sediment delivery from the Stanislaus River is limited by the backwater effects of the San Joaquin River, which can extend several miles up the Stanislaus River.

Samples collected in the San Joaquin River downstream from the Tuolumne River to downstream from the Merced River are finer than the coarser sediments typically found in these respective tributaries. It is not likely these finer gradations are reaches upstream from the confluence with the Merced River because samples from these upstream areas are coarser than samples taken downstream. The finer gradation could be the result of the river eroding and reworking the finer-grained historical flood basin sediments.

### Sedimentation Potential and Analysis of Thalweg Data

Following floods in 1969, 1983 and 1986 it appeared that various reaches of the San Joaquin River no longer had the ability to convey channel design flows. Of primary concern were the reaches between the Tuolumne River (RM 84) and the Merced River (RM 118). Loss of capacity was attributed to sedimentation and vegetation encroachment (COE, 1993). Sedimentation was attributed to erosion of the riverbanks and to erosion of agricultural fields. It has been suggested that encroachment of vegetation has occurred because of the formation of lower elevation bar surfaces along the channel, the products of bank and agricultural erosion coupled with the 1980's drought condition that prevented natural vegetation loss (COE, 1993).

The April 2000 Report presented estimated historic (1914) and existing (1998) sediment transport capacities for the project reach of the San Joaquin River. A comparison between the two time periods showed that transport capacities have increased by about 60 percent in Subreach 3 to about 185 percent in Subreach 1. The indicated increase is caused primarily by increased hydraulic energy associated with deepening and general narrowing of the channel between 1914 and 1998. This corresponds to channel degradation between a few and over 6 feet during this time period.

Sedimentation can also be evaluated in terms of the change in the channel thalweg, or river bottom elevation, over time. The following sections provide a summary of the conclusions that may be drawn from the thalweg data used in the April 2000 report and additional thalweg data collected during subsequent efforts.

### *San Joaquin River*

Figure II-1 shows the 1998 thalweg and the 1951 thalweg for the Comprehensive Study project reach of the San Joaquin River. It is apparent from the comparative profiles that there has been a general trend of aggradation between 1951 and 1998, which appears to be in conflict with the April 2000 assessment that the channel has degraded over time.

Table II-1 summarizes the change in average thalweg elevations measured since 1914 for each subreach of the San Joaquin River. The April 2000 Report shows that each subreach has experienced differing degrees of degradation and aggradation over time. Subreaches 1 and 2 have degraded from 1914 to 1998, however both subreaches have aggraded since 1983. Subreaches 3 and 4 have also experienced overall degradation since 1914, but the rate of degradation has been slowed down considerably since 1983.

**TABLE II-1**

**SUMMARY OF AVERAGE THALWEG ELEVATION CHANGE BY REACH**

| San Joaquin River Subreach | Change from 1914 to 1983 (from April 2000 Report) | Change from 1983 to 1998 (from April 2000 Report) | Net Change 1914 to 1998 (from April 2000 Report) | Change from 1951 to 1998 |
|---|---|---|---|---|
| SR 1 (RM 53.4 to RM 74.8) | -1.3 | 0.2 | -1.1 | 2.2 |
| SR 2 (RM 74.8 to 83.8) | -6.5 | 2.3 | -4.2 | 1.1 |
| SR 3 (RM 83.8 to 99.5) | -5.6 | -0.2 | -5.8 | 2.7 |
| SR 4 (RM 99.5 to RM 118) | -3.2 | -0.7 | -3.9 | 2.0 |

Also shown in Table II-1 is a comparison of average thalweg data for 1951 and 1998. Note that the 1951 thalweg data was not used in the April 2000 Report. Each of the four subreaches appears to have aggraded between 1951 and 1998.

Further analysis was performed using available 1998 thalweg data collected by the Comprehensive Study for their hydraulic modeling effort. Figure II-2 shows the 1998 thalweg and the 1998 San Joaquin River HEC-RAS model thalweg. The data sets are reasonably consistent, further supporting the general trend of aggradation. The differences in the data sets are attributed to the HEC-RAS model choosing the lowest point on a cross-section, which may not correspond with the thalweg. These lowest points may be local depressions not in the main channel. Figure II-3 shows the 1998 thalweg data on the same graph as the 1998 data used in the April 2000 Report. The discrepancy between the two data sets is largely responsible for the conflicting conclusions. The lower 1998 data from the April 2000 Report would lead to a degradation conclusion, while the higher 1998 thalweg model data supports an aggradation conclusion.

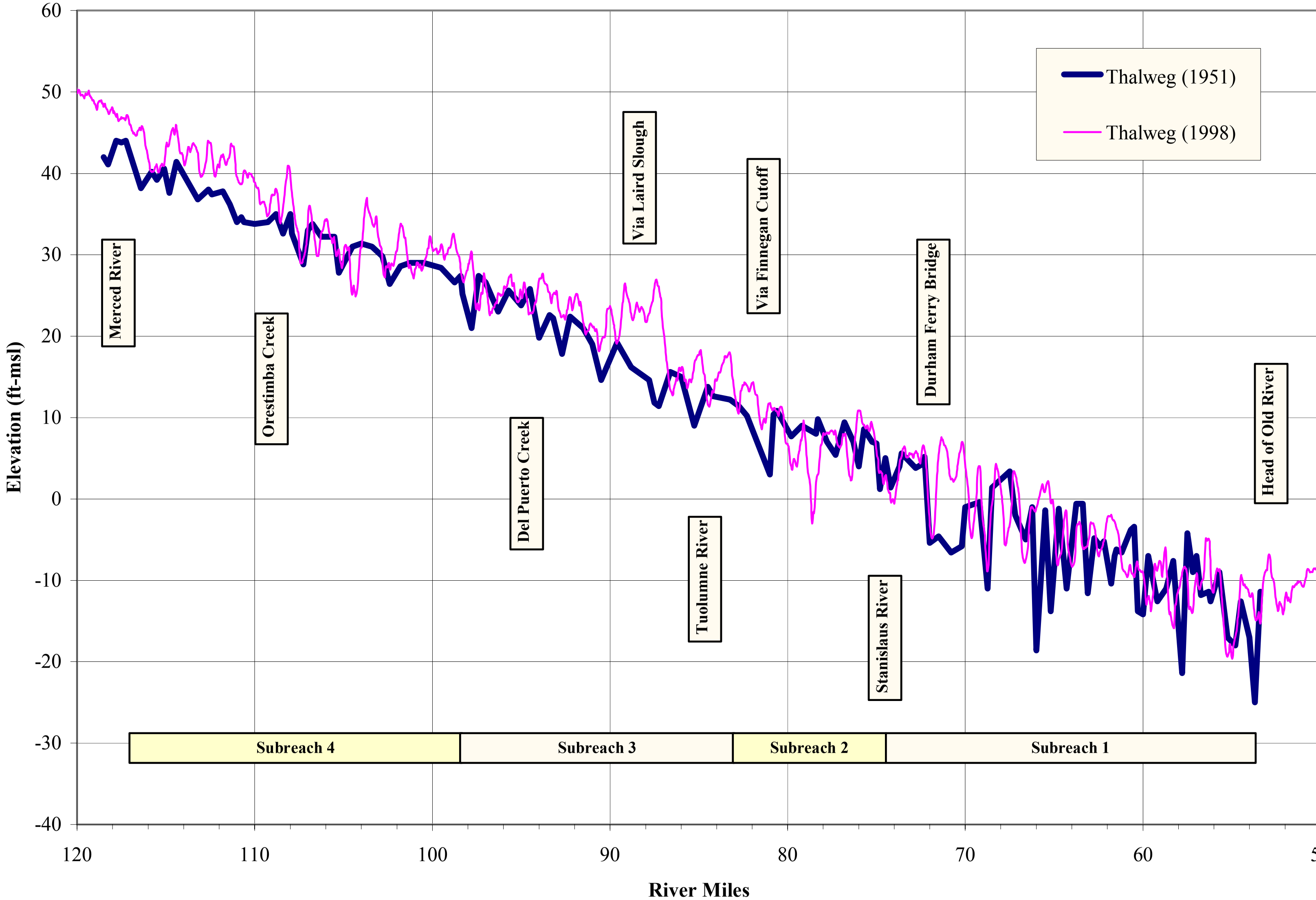



**FIGURE II-1 SAN JOAQUIN RIVER THALWEG - 1951 AND 1998**

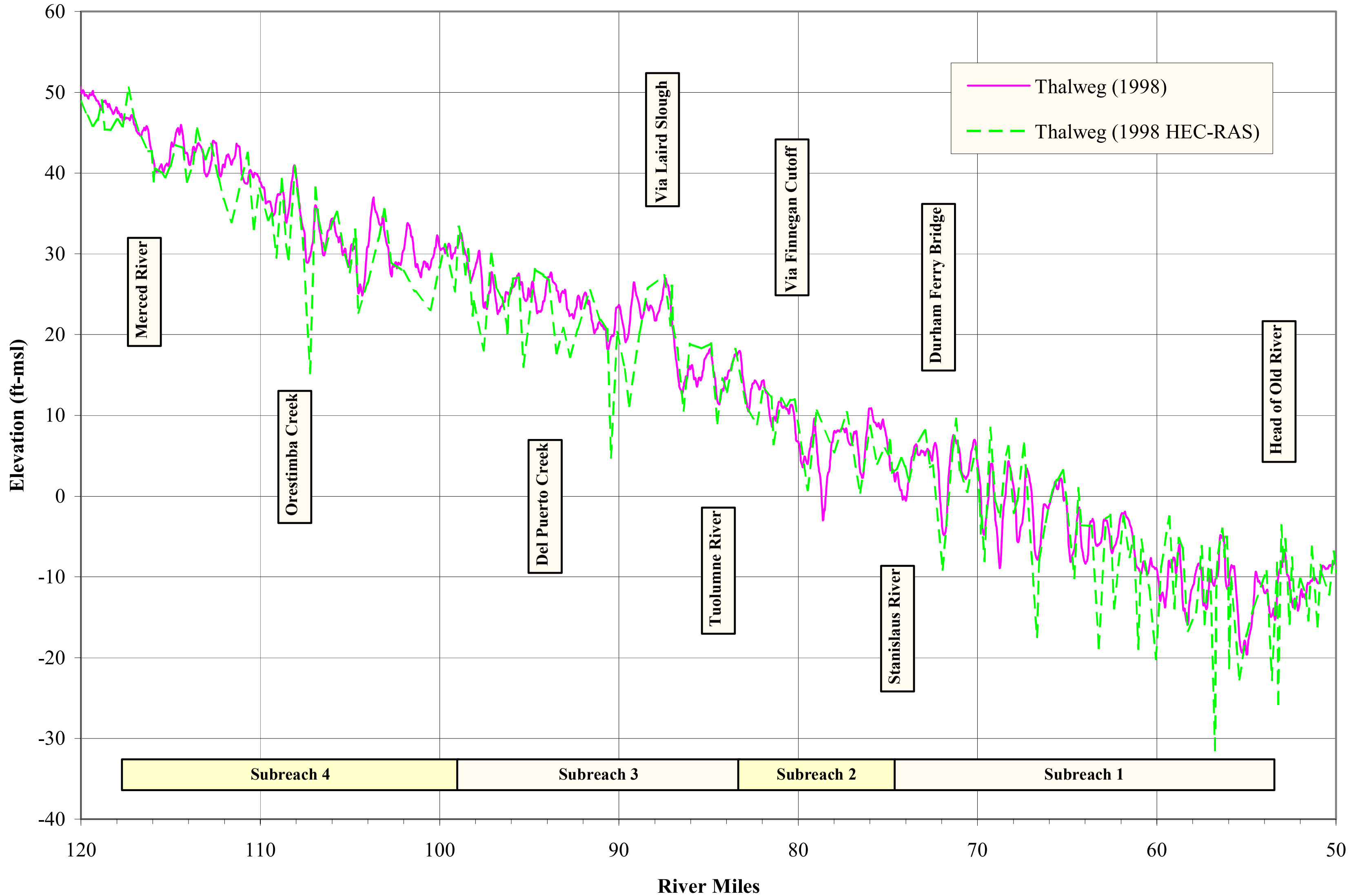



**FIGURE II-2 SAN JOAQUIN RIVER THALWEG 1998 AND 1998 FROM HEC-RAS**

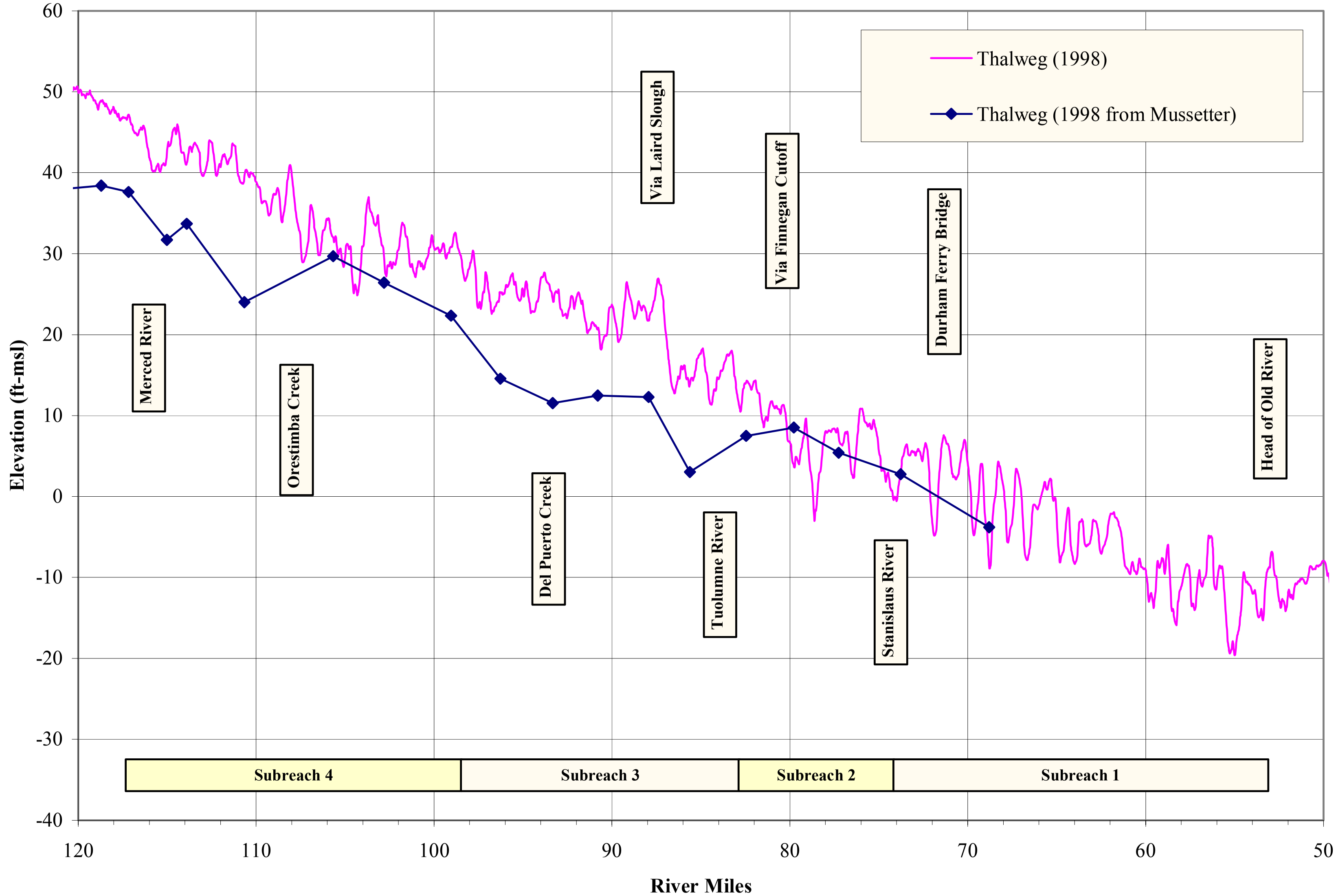



**FIGURE II-3 SAN JOAQUIN RIVER THALWEG 1998 AND 1998 FROM MUSSETTER**

Figure II-4 shows the 1998 thalweg and the 1951 thalweg for a six mile portion of the lower Merced River extending from the mouth to about 2 miles east of Mitchell Road. It is apparent from the comparative profiles plotted in Figure II-4 that there has been a general trend of aggradation between 1951 and 1998 throughout most of this reach. This observation is consistent with recent findings based on comparisons of CALTRANS cross-section profiles taken in 1978 and 1992 at the Hills Ferry/River Road Bridge (Mussetter Engineers, Inc., April 2000). Additional cross-section profile comparisons completed further upstream at the Highway 99 Bridge (Mussetter Engineers, Inc, April 2000) suggest that about three feet of degradation occurred between 1992 and 1997. The sediment from this degradation was a likely contributor to the aggradation at Hills Ferry/River Road Bridge.

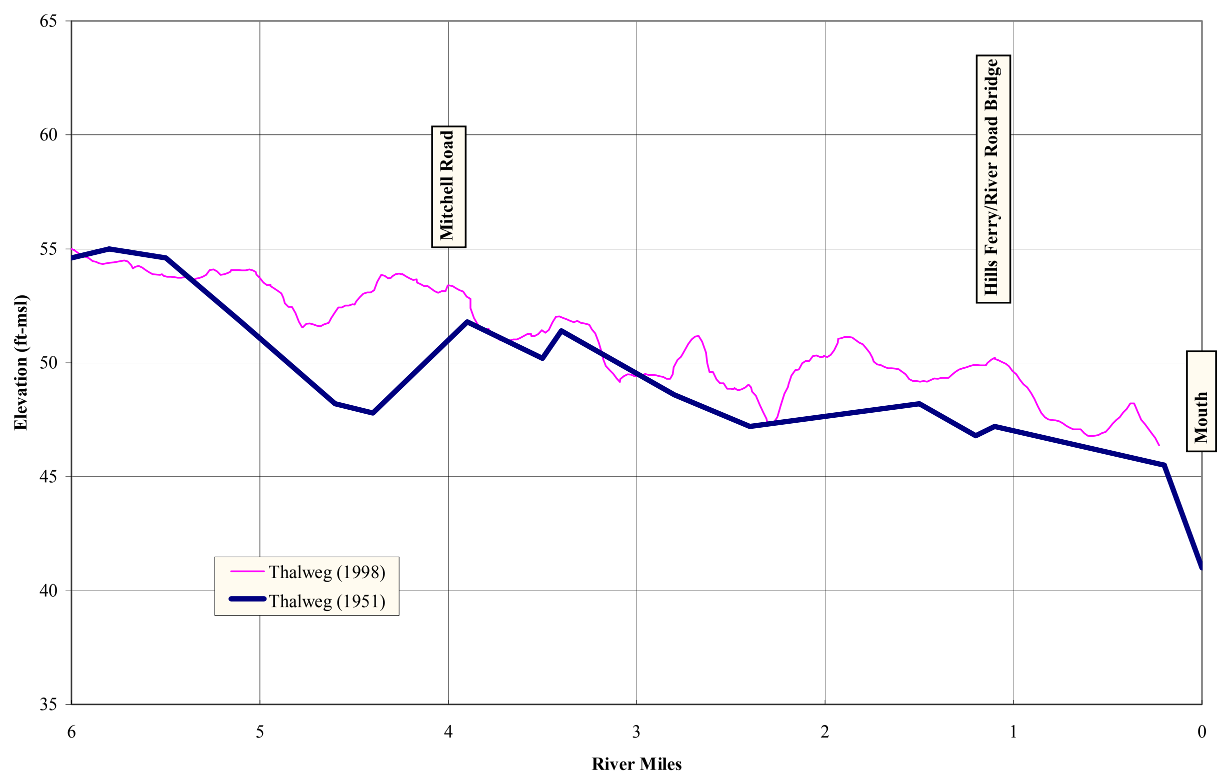



**FIGURE II-4 MERCED RIVER THALWEG**

### *Tuolumne River*

Figure II-5 compares the 1998 thalweg and the 1951 thalweg for a ten mile portion of the lower Tuolumne River extending from the mouth to about 1 mile east of Stone Avenue. It is apparent from the comparative profiles plotted in Figure II-5 that there has been a general trend of aggradation throughout most of this reach between 1951 and 1998. This observation is consistent with recent findings based on comparisons of CALTRANS cross-section profiles taken in 1964 and 1993 at the Shiloh Road Bridge, a location within this reach (Mussetter Engineers, Inc., April 2000). A comparison of cross-section profiles in the upper reaches of the Tuolumne River between Shiloh Road Bridge and Old La Grange Bridge show a dynamic system of aggrading and degrading reaches. The effect these upstream reaches have on the apparent aggradation near the mouth is inconclusive because of the different time periods for which data were available.

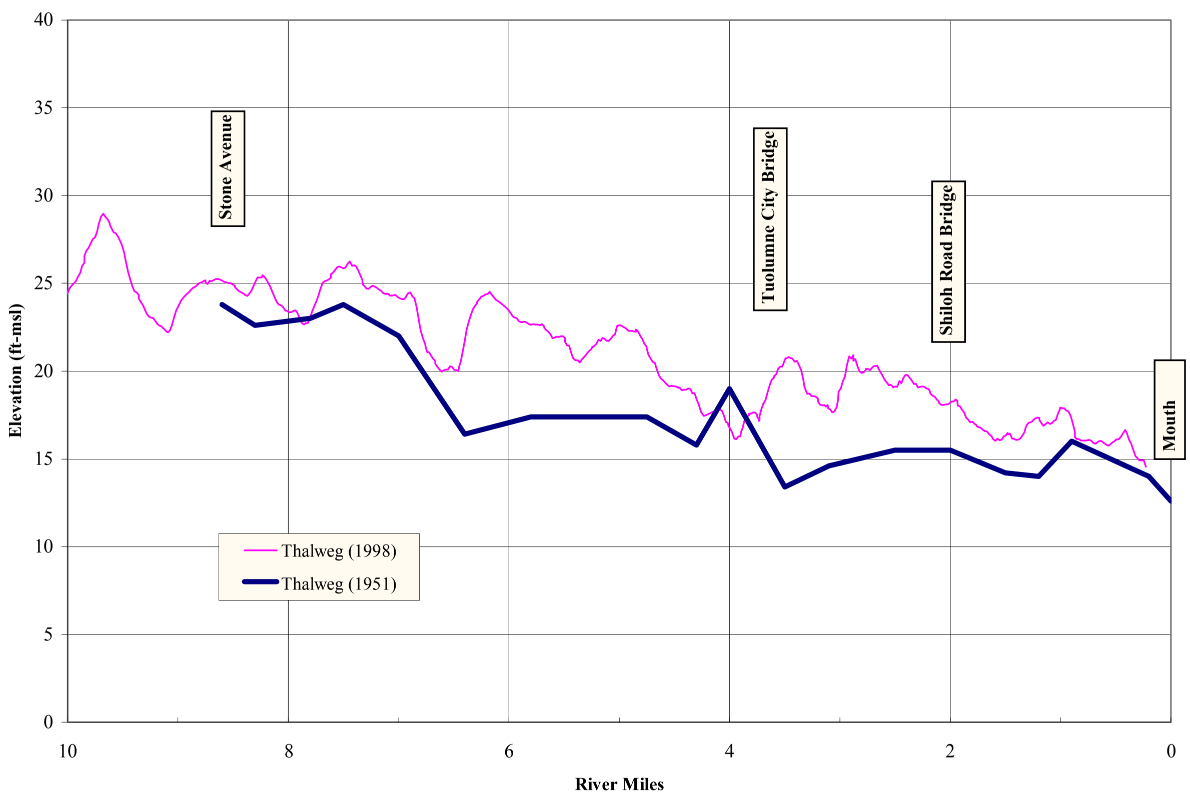



**FIGURE II-5 TUOLUMNE RIVER THALWEG**

### *Stanislaus River*

Figure II-6 shows the 1998 thalweg and the 1951 thalweg for a ten mile portion of the lower Stanislaus River extending from the mouth to about Highway 99. The lower third of this reach includes the mouth up to the head of the Project Levees.[1] A comparison of the two profiles shows that the channel aggraded in excess of five feet in this third of the reach. The area upstream from the Project Levees shows that the channel thalweg has changed little between 1951 and 1998 with the exception of up to four feet of degradation near the Reclamation District 2064 and Reclamation District 2075 intake pumps.

[1] Project Levees are levees that were improved or adopted as part of federal flood control projects and were constructed to convey floodwaters past developed areas.

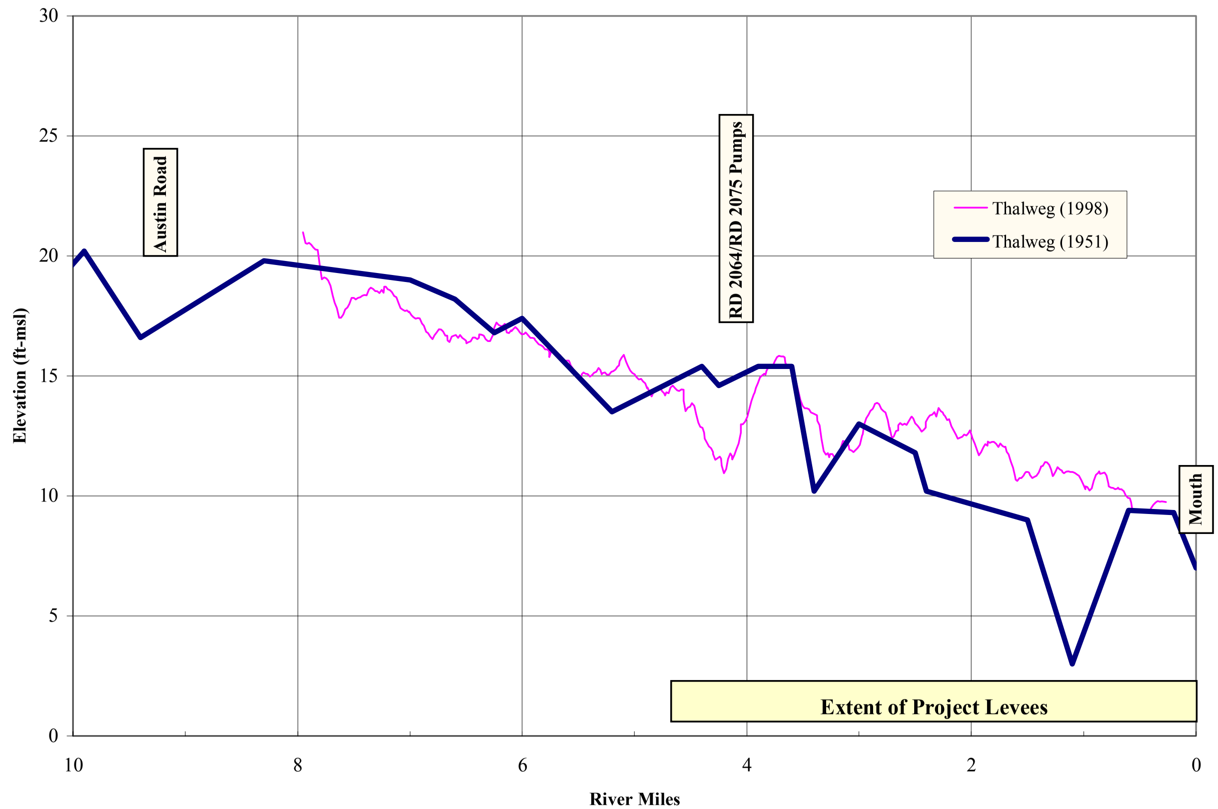



**FIGURE II-6 STANISLAUS RIVER THALWEG**

## Summary and Conclusions

Two distinct and opposite conclusions can be made from the analysis of the 1951 and 1998 thalweg data conducted as part of this effort, and the analysis presented in the April 2000 Report. These conflicting data sets suggest that more work is needed to fully determine the sediment transport characteristics of the San Joaquin River. At this time it would be inappropriate to declare unequivocally that the river is either degrading or aggrading because of the amount of conflicting data. Additional data, such as more frequent historic thalweg data or new thalweg surveys are needed to confirm whether or not the river is aggrading or degrading.

## FLOW SPLITS OF THE LOWER SAN JOAQUIN RIVER

Three major flow splits in the Delta system waterways are important for understanding the distribution of San Joaquin River flood flows in the Delta:

- Flow splits between the San Joaquin River and its distributaries at Paradise Cut;
- Flow splits between the San Joaquin River and Old River near Lathrop; and
- Flow splits between the Old River and Middle River at Union Island.

As described in the *Existing Hydrodynamic Conditions in the Delta During Floods* (COE, 2001), the stage and flow in this portion of the Delta are highly influenced by the combination effects of inflows from the Sacramento River and San Joaquin River and the tidal effect. The historical data does not support the analysis of flow splits.

The DWR Interagency Ecological Program (IEP) has compiled historical hydrodynamics and water quality data of the Bay-Delta tributaries, collected by different agencies at over 120 stations. This data is accessible through their website, and through the participating agencies include Contra Costa Water District, California Data Exchange Center, California Department of Water Resources, East bay Municipal Utility District, National Oceanic and Atmospheric Administration, University of California at Berkeley, U.S. Bureau of Reclamation, and U.S. Geological Survey. The length of records ranges from several months (for some short-term monitoring projects) to more than 70 years. Tables II-2 and II-3 summarize the available flow and stage monitoring stations, which are also illustrated in Figures II-7 and II-8.

Long-term flow measurements of the San Joaquin River and its distributaries are available at Old River at Bacon Island (ROLD024), Middle River and Middle River (RMID015), San Joaquin River at Stockton (RSAN063), and San Joaquin River at Vernalis (RSAN112). The length of records at these stations is more than 10 years, except for the San Joaquin River at Stockton (RSAN063). These stations are located too far away from each other to be sufficient in the determination of flow splits at any of the three bifurcation locations previously described.

Some short-term measurements (about or less than 1 year) are available at Grant Line Canal at Tracy Boulevard (CHGRL009), Victoria Canal (CHVCT000), Old River at Clifton Court Ferry (ROLD040), and Old River near Delta Mendota Canal, SE of Barrier (ROLD047). However, due to their locations and short duration of records, these stations provide little information for characterizing flow splits.

An alternative to derive the flow split relationship by modeling simulation has been evaluated. This approach requires a numerical model that has a good representation of the system during flooding conditions; however, DSM2 and SJRUNET both have limitations in this application. As previously mentioned in Chapter I and discussed in *Existing Hydrodynamic Conditions in the Delta During Floods* (COE, 2001), DSM2 has limitations in the simulation of levee failures and hydrodynamics around bridges and other obstacles in the river, and it has insufficient resolution in Paradise Cut area. SJRUNET covers only a portion of the Delta and the influences of the Sacramento River and tidal ranges are modeled by the downstream rating curves at the model boundaries. Therefore, the inference from simulation results of DSM2 and SJRUNET on the flow splits may be misleading.

## TABLE II-2
## IEP FLOW STATIONS IN THE SOUTH DELTA

| | Station | Agency | UTM E & N (zone 10S, NAD83) | Latitude Longitude (N W) | Location Info |
|---|---|---|---|---|---|
| 1 | CFTRN000 | USGS | 635719 4205781 | 37-59-29 121-27-16 | USGS TURNER, Turner Cut |
| 2 | CHGRL009 | DWR | 636547 4186803 | 37-49-13 121-26-55 | DWR-CD 5300, USGS 313245, Grant Line Canal at Tracy Blvd Bridge |
| 3 | CHGRL009 | USGS | 637012 4186780 | 37-49-12 121-26-36 | DWR-CD 5300, USGS 313245, Grant Line Canal at Tracy Blvd Bridge |
| 4 | CHSWP003 | CDEC | 621000 4184500 | | CDEC HRO, DWR-OM-DFD station, State Water Project California Aqueduct at Harvey O. Banks Delta Pumping Plant |
| 5 | CHSWP003 | DWR | 621000 4184500 | | CDEC HRO, DWR-OM-DFD station, State Water Project California Aqueduct at Harvey O. Banks Delta Pumping Plant |
| 6 | CHVCT000 | USGS | 629368 4192329 | 37-52-16 121-31-45 | *USGS VICT-C, Victoria Canal* |
| 7 | DOM | USGS | 608500 4212500 | | USGS Delta Outflow Monitoring, averaged of stations around |
| 8 | LSHL001 | USGS | 605358 4212207 | 38-03-12 121-47-57 | USGS SHERLN, Sacramento River at Sherman Lake |
| 9 | LSHL003 | USGS | 606615 4209326 | 38-01-38 121-47-07 | USGS ADCP study, San Joaquin River at Mayberry Cut |
| 10 | NDOI | CDEC | 608500 4213000 | | CDEC Delta Outflow Index, averaged of stations around |
| 11 | RCAL009 | DWR | 649300 4205400 | | DWR DSM2 |
| 12 | RMID005 | USGS | 630797 4206903 | 38-00-08 121-30-37 | USGS MIDCOL, Middle River south of Columbia Cut |
| 13 | RMID015 | DWR | 628901 4200275 | 37-56-34 121-31-59 | DWR-CD 5468, USGS 312676, Middle River at Middle River |
| 14 | RMID015 | USGS | 628901 4200275 | 37-56-34 121-31-59 | DWR-CD 5468, USGS 312676, Middle River at Middle River |
| 15 | ROLD024 | CDEC | 625516 4203466 | 37-97-20 121-57-10 | CDEC BAC, DWR-CD 5250, USGS 313405, Old River at Bacon Island |
| 16 | ROLD024 | DWR | 625507 4203460 | 37-58-19 121-34-16 | CDEC BAC, DWR-CD 5250, USGS 313405, Old River at Bacon Island |
| 17 | ROLD024 | USGS | 625510 4203244 | 37-58-12 121-34-16 | CDEC BAC, DWR-CD 5250, USGS 313405, Old River at Bacon Island |
| 18 | ROLD040 | DWR | 627559 4187645 | 37-49-45 121-33-02 | DWR-CD 5340, USGS 312970, Old River at Clifton Court Ferry |
| 19 | ROLD040 | USGS | 627538 4187368 | 37-49-36 121-33-03 | DWR-CD 5340, USGS 312970, Old River at Clifton Court Ferry |
| 20 | ROLD047 | DWR | 628324 4185592 | 37-48-38 121-32-32 | USGS OLDDMC, DWR-CD 5366, Old River near Delta Mendota Canal (SE of barrier) |
| 21 | ROLD047 | USGS | 628448 4185501 | 37-48-35 121-32-27 | USGS OLDDMC, DWR-CD 5366, Old River near Delta Mendota Canal (SE of barrier) |
| 22 | RSAN018 | USBR | 615060 4212215 | 38-03-08 121-41-19 | USBR JER, USGS 337190, San Joaquin River at Jersey Point |
| 23 | RSAN018 | USGS | 614866 4212182 | 38-03-07 121-41-27 | USBR JER, USGS 337190, San Joaquin River at Jersey Point |
| 24 | RSAN046 | USGS | 634413 4209521 | 38-01-31 121-28-07 | USGS SJR-TC, San Joaquin River between Turner Cut and Columbia Cut |
| 25 | RSAN063 | USGS | 646807 4199806 | 37-56-09 121-19-46 | USGS 304810, San Joaquin River at Stockton |
| 26 | RSAN112 | CDEC | 652848 4170077 | 37-66-70 121-26-70 | CDEC VER/VNS, USBR VER, USGS 11303500, San Joaquin River at Vernalis |
| 27 | RSAN112 | DWR | 653079 4171092 | 37-40-34 121-15-51 | CDEC VER/VNS, USBR VER, USGS 11303500, San Joaquin River at Vernalis |

## TABLE II-2 (CONTINUED)

| | Station | Agency | UTM E & N (zone 10S, NAD83) | Latitude Longitude (N W) | Location Info |
|---|---|---|---|---|---|
| 28 | RSAN112 | USBR | 652933 4171059 | 37-40-33 121-15-57 | CDEC VER/VNS, USBR VER, USGS 11303500, San Joaquin River at Vernalis |
| 29 | RSAN112 | USGS | 653079 4171092 | 37-40-34 121-15-51 | CDEC VER/VNS, USBR VER, USGS 11303500, San Joaquin River at Vernalis |
| 30 | SLDUT007 | USGS | 617023 4207958 | 38-00-49 121-40-01 | USGS 313433, Dutch Slough at Jersey Island |
| 31 | SLMAY002 | USGS | 607555 4210109 | 38-02-03 121-46-28 | USGS MAY-SL, Mayberry Slough |
| 32 | SLTRM004 | DWR | 615298 4216072 | 38-05-13 121-41-07 | DWR-CD 5060, USGS 337080, Three Mile Slough at San Joaquin River |
| 33 | SLTRM004 | USGS | 615273 4216133 | 38-05-15 121-41-08 | DWR-CD 5060, USGS 337080, Three Mile Slough at San Joaquin River |

## TABLE II-3
## IEP STAGE STATIONS IN THE SOUTH DELTA

| | Station | Agency | UTM E & N (zone 10S, NAD83) | Latitude Longitude (N W) | Location Info |
|---|---|---|---|---|---|
| 1 | CHGRL009 | DWR | 636547 4186803 | 37-49-13 121-26-55 | DWR-CD 5300, USGS 313245, Grantline Canal at Tracy Blvd Bridge |
| 2 | CHGRL009 | USGS | 637012 4186780 | 37-49-12 121-26-36 | DWR-CD 5300, USGS 313245, Grantline Canal at Tracy Blvd Bridge |
| 3 | CHGRL012 | DWR | 639963 4186810 | 37-49-13 121-26-38 | DWR-CD 5310, Grantline Canal at Head |
| 4 | CHWST000 | DWR | 626900 4188315 | | DWR-OM Clifton Court Forebay Radial Gates |
| 5 | RMID007 | DWR | 629700 4206855 | 38-00-07 121-31-22 | DWR-CD 5460, Middle River at Bacon Island |
| 6 | RMID015 | DWR | 628901 4200275 | 37-56-34 121-31-59 | DWR-CD 5468, USGS 312676, Middle River at Middle River |
| 7 | RMID015 | USGS | 628901 4200275 | 37-56-34 121-31-59 | DWR-CD 5468, USGS 312676, Middle River at Middle River |
| 8 | RMID023 | DWR | 632875 4194605 | 37-53-28 121-29-20 | USBR VIC, DWR-CD 5500, Middle River at Borden Highway |
| 9 | RMID023 | USBR | 632923 4194605 | 37-53-28 121-29-18 | USBR VIC, DWR-CD 5500, Middle River at Borden Highway |
| 10 | RMID027 | DWR | 635824 4193574 | 37-52-53 121-27-20 | DWR-CD 5503, Middle River at Tracy Blvd |
| 11 | RMID040 | DWR | 643024 4188486 | 37-50-04 121-22-29 | DWR-CD 5540, Middle River at Mowry Bridge, 1.7 km N of Old River |
| 12 | ROLD024 | CDEC | 625516 4203466 | 37-97-20 121-57-10 | CDEC BAC, DWR-CD 5250, USGS 313405, Old River at Bacon Island |
| 13 | ROLD024 | DWR | 625507 4203460 | 37-58-19 121-34-16 | CDEC BAC, DWR-CD 5250, USGS 313405, Old River at Bacon Island |
| 14 | ROLD024 | USGS | 625510 4203244 | 37-58-12 121-34-16 | CDEC BAC, DWR-CD 5250, USGS 313405, Old River at Bacon Island |
| 15 | ROLD034 | CCWD | 625871 4194731 | | DWR-CD 5270, CCWD pumping station, Old River near Byron |
| 16 | ROLD034 | DWR | 625871 4194731 | 37-53-28 121-34-09 | DWR-CD 5270, CCWD pumping station, Old River near Byron |
| 17 | ROLD040 | DWR | 627559 4187645 | 37-49-45 121-33-02 | DWR-CD 5340, USGS 312970, Old River at Clifton Court Ferry |
| 18 | ROLD040 | USGS | 627538 4187368 | 37-49-36 121-33-03 | DWR-CD 5340, USGS 312970, Old River at Clifton Court Ferry |
| 19 | ROLD046 | DWR | 628028 4185772 | 37-48-44 121-32-44 | DWR-CD 5365, Old River near Delta Mendota Canal (NW of barrier) |
| 20 | ROLD047 | DWR | 628324 4185592 | 37-48-38 121-32-32 | USGS OLDDMC, DWR-CD 5366, Old River near Delta Mendota Canal (SE of barrier) |
| 21 | ROLD047 | USGS | 628448 4185501 | 37-48-35 121-32-27 | USGS OLDDMC, DWR-CD 5366, Old River near Delta Mendota Canal (SE of barrier) |
| 22 | ROLD059 | CDEC | 636575 4185107 | 37-80-50 121-44-90 | CDEC OLR, DWR-CD 5380, Old River at Tracy Blvd |
| 23 | ROLD059 | DWR | 636575 4185108 | 37-48-18 121-26-55 | CDEC OLR, DWR-CD 5380, Old River at Tracy Blvd |

## TABLE II-3 (CONTINUED)

| | Station | Agency | UTM E & N (zone 10S, NAD83) | Latitude Longitude (N W) | Location Info |
|---|---|---|---|---|---|
| 24 | ROLD074 | DWR | 647111 4185567 | 37-48-27 121-19-44 | DWR-CD 5400, Old River at Head |
| 25 | RSAN007 | CDEC | 605190 4208259 | 38-01-04 121-48-06 | CDEC ANH, DWR-CD 5020, San Joaquin River at Antioch between lights 7 & 8 |
| 26 | RSAN007 | DWR | 605190 4208259 | 38-01-04 121-48-06 | CDEC ANH, DWR-CD 5020, San Joaquin River at Antioch between lights 7 & 8 |
| 27 | RSAN018 | USBR | 615060 4212215 | 38-03-08 121-41-19 | USBR JER, USGS 337190, San Joaquin River at Jersey Point |
| 28 | RSAN018 | USGS | 614866 4212182 | 38-03-07 121-41-27 | USBR JER, USGS 337190, San Joaquin River at Jersey Point |
| 29 | RSAN032 | DWR | 623573 4218012 | 38-06-12 121-35-26 | USBR SAL, DWR-CD 5100, San Joaquin River at San Andreas Landing |
| 30 | RSAN032 | USBR | 623553 4218043 | 38-06-13 121-35-27 | USBR SAL, DWR-CD 5100, San Joaquin River at San Andreas Landing |
| 31 | RSAN043 | CDEC | 631964 4212224 | 38-05-00 121-49-60 | CDEC VNI&VNE, DWR-CD 5580, San Joaquin River at Venice Island |
| 32 | RSAN043 | DWR | 631979 4212256 | 38-03-01 121-29-45 | CDEC VNI&VNE, DWR-CD 5580, San Joaquin River at Venice Island |
| 33 | RSAN052 | DWR | 638879 4206512 | 37-59-51 121-25-06 | DWR-CD 5620, San Joaquin at Rindge Pump |
| 34 | RSAN058 | DWR | 643630 4202740 | 37-57-46 121-21-54 | DWR-CD 5660, Stockton Ship Channel at Burns Cutoff |
| 35 | RSAN063 | USGS | 646807 4199806 | 37-56-09 121-19-46 | USGS 304810, San Joaquin River at Stockton |
| 36 | RSAN072 | DWR | 647632 4191928 | 37-51-53 121-19-18 | DWR-CD 5740, San Joaquin River at Brandt Bridge |
| 37 | RSAN112 | CDEC | 652848 4170077 | 37-66-70 121-26-70 | CDEC VER/VNS, USBR VER, USGS 11303500, San Joaquin River at Vernalis |
| 38 | RSAN112 | DWR | 653079 4171092 | 37-40-34 121-15-51 | CDEC VER/VNS, USBR VER, USGS 11303500, San Joaquin River at Vernalis |
| 39 | RSAN112 | USBR | 652933 4171059 | 37-40-33 121-15-57 | CDEC VER/VNS, USBR VER, USGS 11303500, San Joaquin River at Vernalis |
| 40 | RSAN112 | USGS | 653079 4171092 | 37-40-34 121-15-51 | CDEC VER/VNS, USBR VER, USGS 11303500, San Joaquin River at Vernalis |
| 41 | SLDUT007 | USGS | 617023 4207958 | 38-00-49 121-40-01 | USGS 313433, Dutch Slough at Jersey Island |
| 42 | SLFRC005 | DWR | 654074 4193865 | 121-14-53 37-52-52 | DWR-CD 2805, French Camp Slough near French Camp |
| 43 | SLRCK005 | DWR | 619595 4203864 | 37-58-35 121-38-18 | DWR-CD 5220, Rock Slough at Contra Costa Canal intake |
| 44 | SLTMP000 | DWR | 639366 4183521 | 37-47-25 121-25-02 | DWR-CD 5420&5421, Tom Paine Slough above Intake Structure |
| 45 | SLTMP017 | DWR | 645331 4181065 | 37-46-02 121-21-00 | DWR-CD 5425, Tom Paine Slough at Pescadero Pumping Plant # 6 |
| 46 | SLTRM004 | DWR | 615298 4216072 | 38-05-13 121-41-07 | DWR-CD 5060, USGS 337080, Three Mile Slough at San Joaquin River |
| 47 | SLTRM004 | USGS | 615273 4216133 | 38-05-15 121-41-08 | DWR-CD 5060, USGS 337080, Three Mile Slough at San Joaquin River |

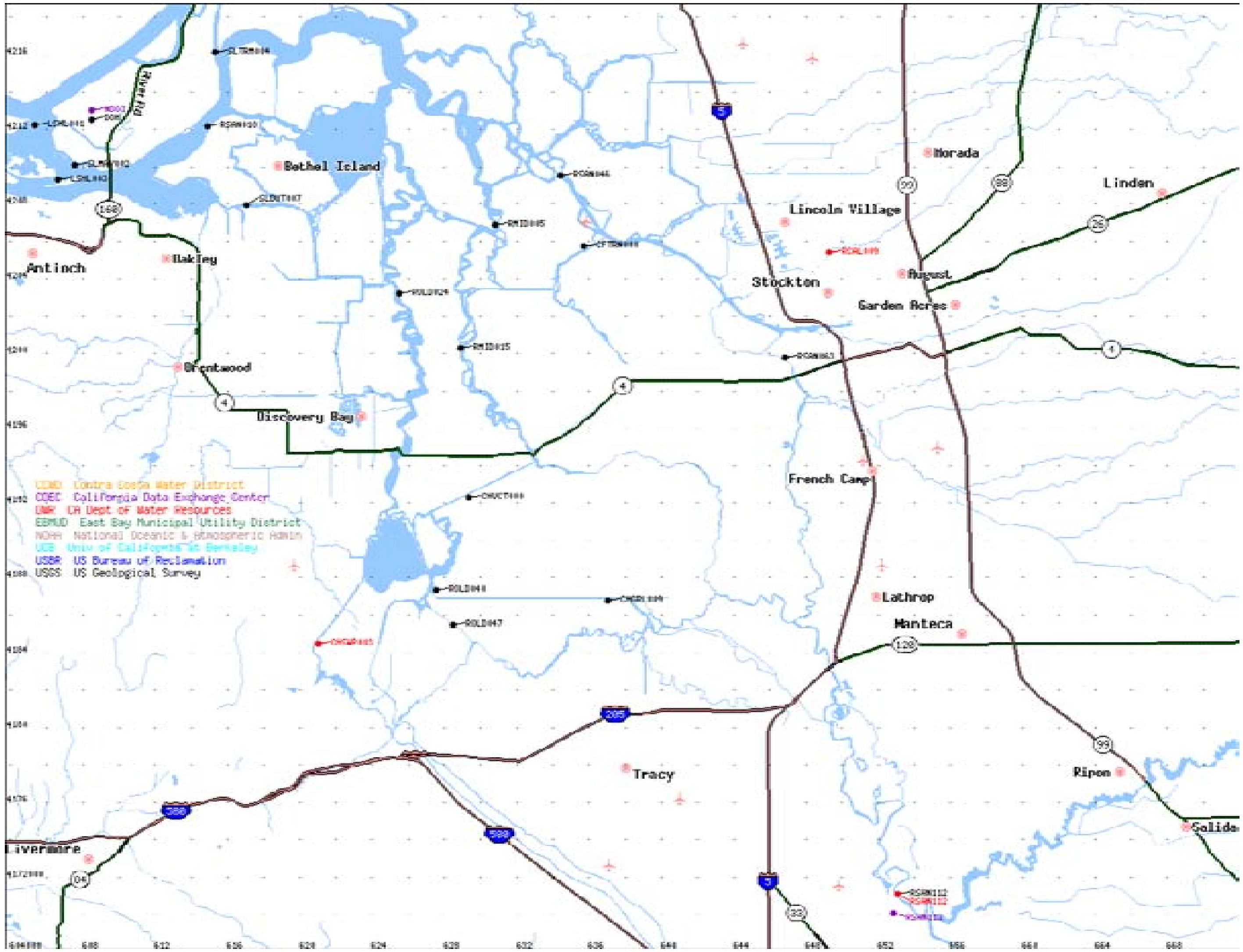



**FIGURE II-7 IEP FLOW STATIONS IN THE SOUTH DELTA**

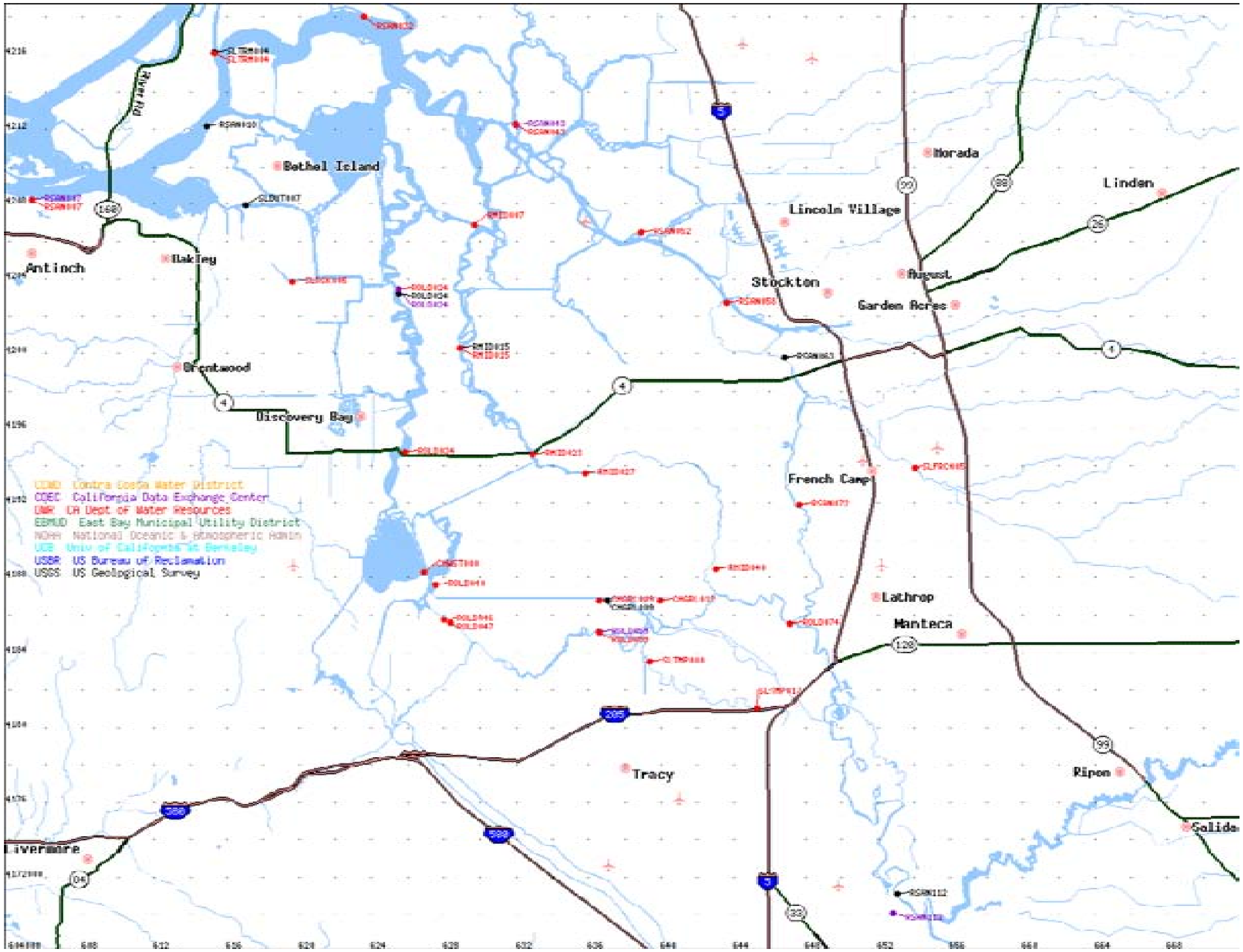



**FIGURE II-8 IEP STAGE STATIONS IN THE SOUTH DELTA**

## TIDAL EFFECTS IN THE LOWER SAN JOAQUIN RIVER

The determination of a downstream boundary for the Comprehensive Study is needed to maintain focus on the improvements to the San Joaquin River and identify potential areas of impact in the Delta. Areas where the San Joaquin River flood flows have little impact on the river stage will be excluded from the discussion of alternatives and improvements and will not require hydraulic mitigation.

### Factors Controlling River Stage in the Delta

The Delta is a convergence of ocean tides and river flows from the Sacramento River, the San Joaquin River and several east-side tributaries. The river stage at any point in the Delta is a result of hydraulic balance among all the controlling factors.

Figures II-9 through 2-11 show the recorded flow and stages at selected measurement points along the San Joaquin River, the Old River and the Middle River from December 1, 1996 to February 28, 1997. Many stations, including San Joaquin River at Vernalis, experienced gaps in recording flow or stage data during the 1997 event. The tidal effects on river stage are typically shown in a frequency of approximately two cycles per day, and a larger tidal effect is observed roughly twice each month.

### River Stages During the 1997 Flood Event

#### *San Joaquin River*

The importance of the San Joaquin River flow in the determination of the river stage in Delta waterways varies from location to location. Figure II-9 shows the comparison of San Joaquin River stages at various locations with the concurrent flood hydrographs of the Sacramento River at Freeport and the San Joaquin River at Vernalis during the 1997 flood.

At Vernalis, the river stage was not influenced by tide and thus, the river stage is solely determined by the San Joaquin River flow. However, at Jersey Point (RSAN018), the river stage was constantly affected by tide, as indicated by the zigzag pattern of river stage present throughout the three-month period shown in Figure II-9. On January 3 through 5, when the flood flows reached their peaks in both major tributaries, the tidal effect was still strong enough to cause the river stage to oscillate with about one foot of amplitude. Although the amplitude was largely reduced from the 4 feet observed in the early December of 1996, the stage oscillation is still clear. The stage oscillation was reduced because the space in the river channel vacated by tide recess was filled instantly by the flood flows from the tributaries. In addition, the river stage at Jersey Point is more correlated to the Sacramento River flow at Freeport than to the San Joaquin

River flow at Vernalis. The second flood peak of the Sacramento River in late January is reflected by the river stage at Jersey Point, while the San Joaquin River flow at Vernalis was relatively constant during that period of time.

The stage records of the Stockton Ship Channel at Burns Cutoff (RSAN058) are not available after December 31, 1996. Based on the available records, the tidal effects are evident at this location and the stage variation is similar to that of the San Joaquin River at Jersey Point.

At the upstream location at Brandt Bridge (RSAN072), the tidal effects are observed for most of the period from December 1996 through February 1997; however, the stage oscillation due to tidal effects is small compared to the river stage increase caused by the flood flow. Compared to the downstream stations, river stage at Brandt Bridge has a much higher correlation to that at Vernalis and is less affected by tide.

***Old River***

Stage records along the Old River during the 1997 flood are available at Old River at Head (ROLD074), Old River at Tracy Boulevard (ROLD059), Grantline Canal at Tracy Boulevard (CHRGL009), Old River at Byron, CCWD Pumping Station (ROLD034), and Old River at Bacon Island (ROLD024). Figure II-8 shows the comparison of river stages at these locations.

Tidal effects are evident at locations downstream from Tracy Boulevard. At the head of the Old River, the tidal effects were suppressed by the flood flow after the recorded flow at Vernalis reached about 30,000 cfs. The river stages of Old River at Head (ROLD074), Old River at Tracy Boulevard (ROLD059), and Grantline Canal at Tracy Boulevard (CHRGL009) appear to be more influenced by the San Joaquin River flow at Vernalis. On the other hand, the stages of the remaining downstream locations are more stable and seem to have more correlation to the Sacramento River flow.

***Middle River***

The Middle River splits flow from the Old River at Union Island. Stage records along the Middle River during the 1997 flood are available at Middle River at Mowry Bridge (RMID040), Middle River at Tracy Boulevard (RMID027), Middle River at Borden Highway (RMID023), and Middle River at Middle River (RMID015). However, the records of Middle River at Mowry Bridge are missing during the high flow period. Figure II-11 shows the comparison of river stages at these locations.

While tidal effects are evident in all the available stage data for Middle River, San Joaquin River flows appear to have less influence on the river stage after Middle River passes the Borden Highway (Highway 4).

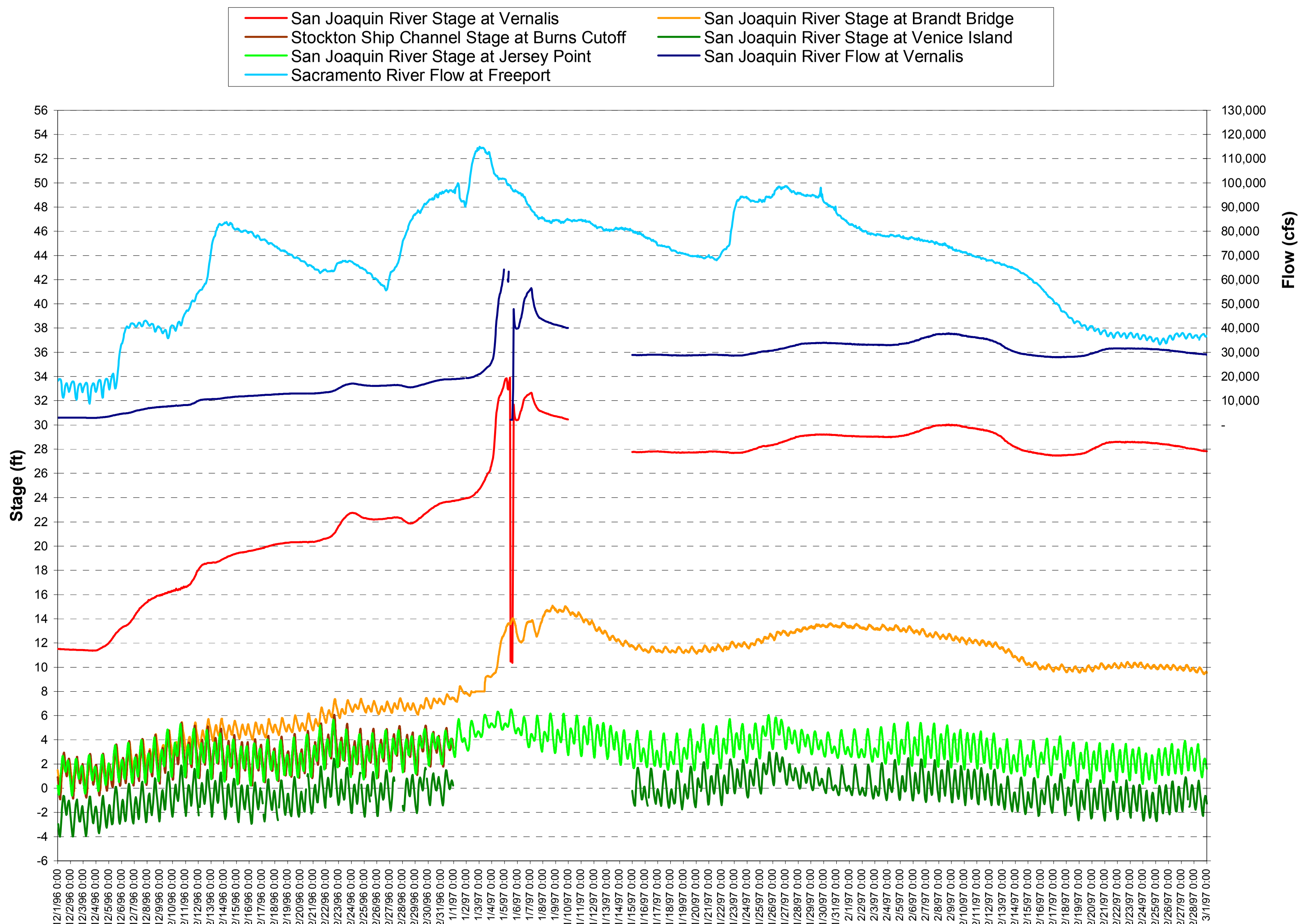



**FIGURE II-9 REAL-TIME RIVER STAGES IN THE SAN JOAQUIN RIVER DURING THE 1997 FLOOD**

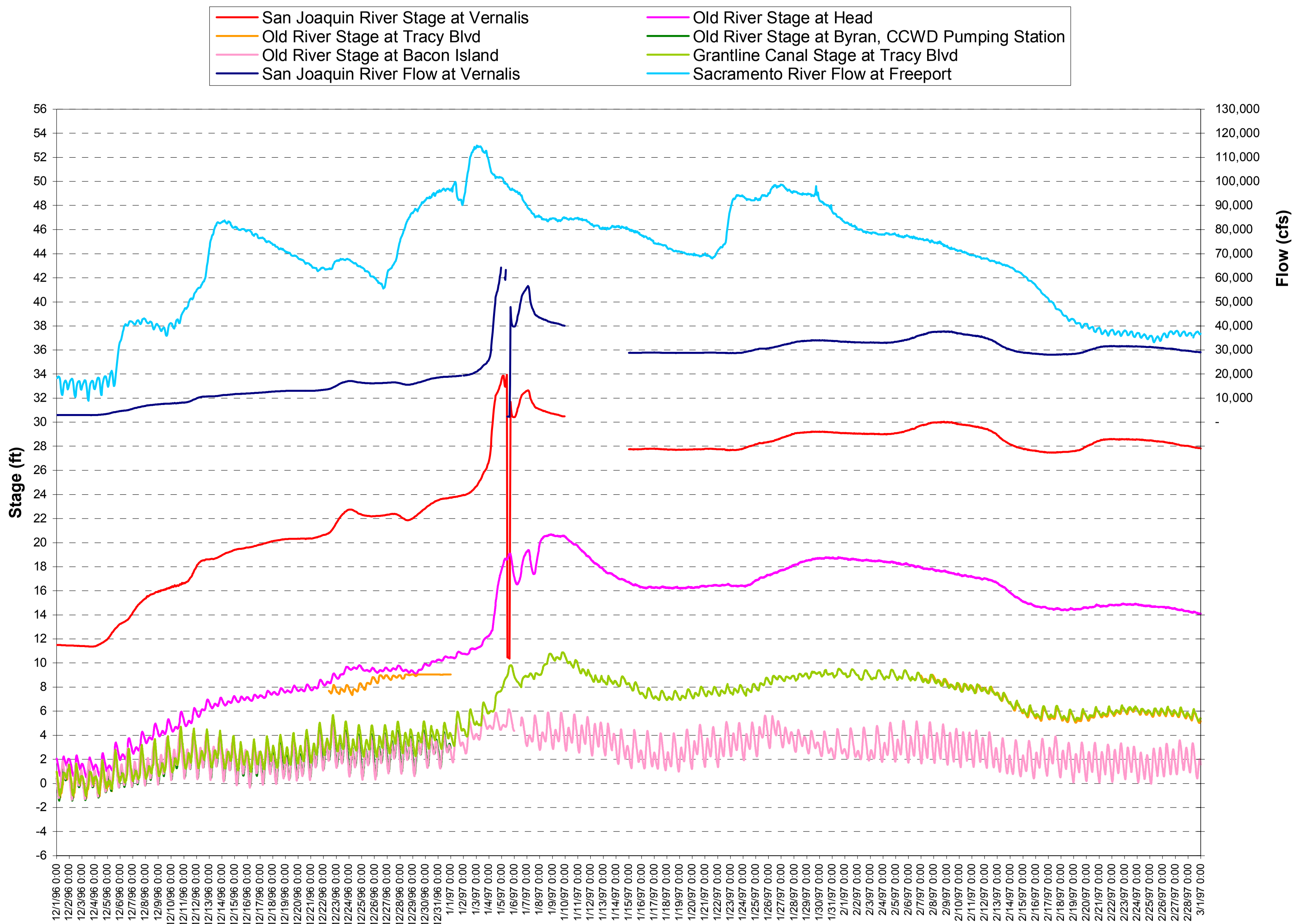



**FIGURE II-10 REAL-TIME RIVER STAGES IN THE OLD RIVER DURING THE 1997 FLOOD**

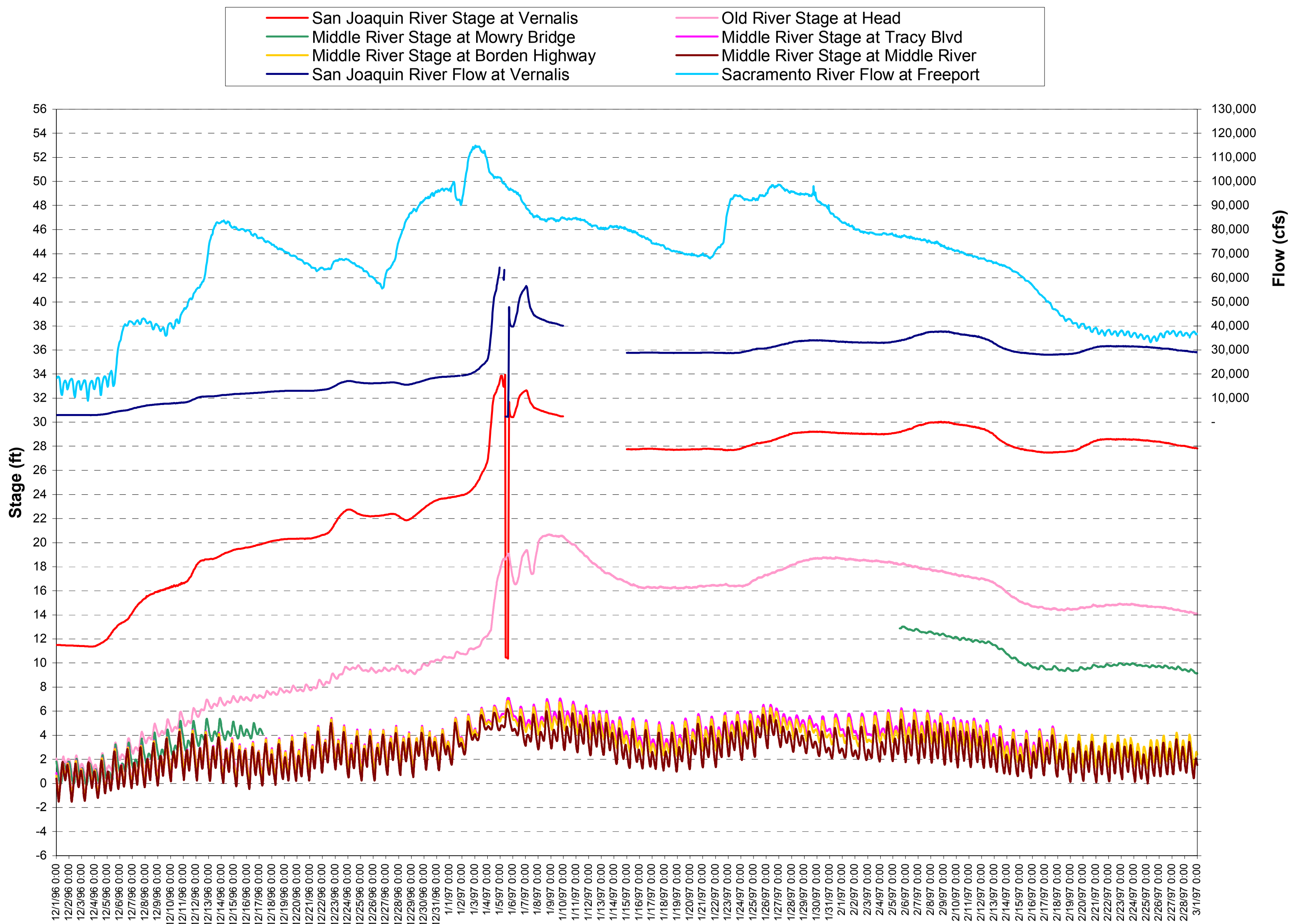



**FIGURE II-11 REAL-TIME RIVER STAGES IN THE MIDDLE RIVER DURING THE 1997**

## Flood Downstream Boundary Delineation for the Study Area

The determination of a downstream boundary for the study is important in order to identify potential areas of hydraulic impact. However, because of the complex hydrodynamic conditions in the Delta, the delineation to isolate the influenced area of San Joaquin River flows is not straightforward. The delineation of the downstream boundary was approached using historical data and a DSM2 model sensitivity analysis.

### *Historical Data*

The river stage at any location in the Delta is a result of tidal flow and concurrent flows from the Sacramento River, the San Joaquin River, and east-side tributaries. The locations where the tide solely determines the river stage may only exist in the San Francisco Bay, and locations where the flood flows solely determine the river stages may exist only at the upstream point (such as Vernalis) beyond the Delta backwater influence. The stage at any location in between will be determined jointly by all inflows (including tides). In other words, the influence of the San Joaquin River flow on the river stages in the Delta is event-dependent.

For the 1997 flood, the stage records suggest that the San Joaquin River flow has significantly less influence on the river stages at and downstream from Stockton Ship Channel at Burns Cutoff (RSAN058), Middle River at Tracy Boulevard (RMID027), and Old River at Byron, CCWD Pumping Station (ROLD034). There are no data available along the Old River to refine the location between Old River at Byron (ROLD034) and Old River at Tracy Boulevard (ROLD059). Central Valley Project (CVP) and State Water Project (SWP) exports at the South Delta may influence the hydraulic balance in their vicinity. However, in 1997 flood, the CVP/SWP export was small compared to the magnitude of floodwater coming into the Delta.

The 1997 flood is classified as an 89-year event for 1-day duration of San Joaquin River flow at Vernalis (*Comprehensive Study In-Progress Review Report, Appendix A, Synthetic Hydrology Technical Documentation*, October 2000). When a flood with a higher or lower return period (ranging from 10 to 500 years for this study) is considered, the area where the San Joaquin River flow has little influence on river stage will move upstream or downstream from the area for the 1997 flood. The extent of the movement cannot be clearly defined without specifying the concurrent tidal flows and flows from the Sacramento River and east-side tributaries.

### *DSM2 Model Sensitivity*

River stage data during historical flood conditions represent the results of the historical combination of hydrological conditions in the Delta. They are not sufficient for the determination of the influence from the full range of the San Joaquin River flow that will be examined in the current study. Therefore, DSM2 can be used to supplement the historical records to determine the influence of the San Joaquin River flow on river stage in the Delta.

Model sensitivity is used to evaluate the relative changes of a certain measurement (e.g., river stage in the Delta) respective to the changes in a boundary condition or other controlling factors (e.g., San Joaquin River flow). If the model sensitivity is low, the change in the controlling factor has a relative small impact on a model output. The DSM2 model simulations performed by DWR staff to verify the applicability of the existing model can be used as an example.

DWR staff determined that the historical records of San Joaquin River at Vernalis are erroneous after January 4, 1997. Compared to the historical records, the synthetic (or corrected) hydrograph of the San Joaquin River at Vernalis shows a roughly 2,000-cfs reduction in the flood peak on January 5, a restored flood peak of 35,000 cfs on January 9, and elevated flows after January 8. The difference between the calibration results before and after the modification provides opportunities to examine the sensitivities of river stage at various locations in the Delta to the changes in the San Joaquin River flow.

Hydrographs and stage histograms at selective locations in the Delta under the historical and synthetic hydrographs of the San Joaquin River were provided by DWR staff and compiled in Attachment A. The comparison of these two sets of calibration results suggests the following model sensitivity to the change in the San Joaquin River flow:

- **Locations with Low Sensitivity.** The change in the San Joaquin River flow does not cause any visible difference in the stage. These locations include Stockton Ship Channel at Burns Cutoff (RSAN058), San Joaquin River at Jersey Point (RSAN018), San Joaquin River at Antioch (RSAN007), Old River at Bacon Island (ROLD024), Middle River at Middle River (RMID015), Middle River at Bacon Island (RMID007), Sacramento River at North of Delta Cross Channel (RSAC128), Sacramento River at Rio Vista (RSAC101), and Sacramento River at Collinsville (RSAC081).
- **Locations with Moderate Low Sensitivity.** The change in the San Joaquin River flow causes minor change in the river stage, and the erroneous peak flow was not reflected by the river stage in the original simulation with the unadjusted San Joaquin River flow. These locations include CCWD Intake (ROLD034), and Middle River at Highway 4 (RMID023).
- **Locations with Moderate High Sensitivity.** The change in the San Joaquin River flow causes minor change in the river stages, and a more prominent change in the peak flow. These locations include San Joaquin River at Stockton (RSAN063), Old River near DMC, SE of Barrier (ROLD047), and Old River near DMC, NW of Barrier (ROLD046).
- **Locations with High Sensitivity:** The simulated river stage changes significantly after the modification of the San Joaquin River flow. These locations include San Joaquin River at Brandt Bridge (RSAN072), Old River at Head (ROLD074), Old River at Tracy Boulevard (ROLD059), and Middle River at Tracy Boulevard (RMID027).

For the 1997 flood, the area in which changes in San Joaquin River flow have little impact on the river stage (i.e., the area defined by the low sensitivity group) is downstream from Stockton Ship Channel at Burns Cutoff (RSAN058), Middle River at Highway 4 (RMID023), and Old River at CCWD Intake (ROLD034). This area is generally agrees with the area derived from the analysis of the historical data.

#### *Conclusions on Downstream Study Boundary Delineation*

As presented in *Existing Hydrodynamic Conditions in the Delta during Floods* (COE, 2001), the Delta hydrodynamics is controlled simultaneously by the inflows from the Sacramento River, the San Joaquin River, and the tides. The influence zone of the San Joaquin River inflow can only be determined in a case-by-case manner. Based on the 1997 flood, the downstream boundary of the study area can be defined roughly by the Stockton Ship Channel at Burns Cutoff on the San Joaquin River, the Borden Highway (Highway 4) on the Middle River, and the Clifton Court

Forebay on the Old River. Historical data and the analysis of DSM2 model sensitivity support this downstream boundary. Beyond this boundary, changes in the San Joaquin River flow are expected to have insignificant impact on the river stage. However, the boundary may move upstream or downstream depending on the magnitude of flood under consideration. One of the observations in the analysis of Delta hydrodynamics during floods reported in *Existing Hydrodynamic Conditions in the Delta during Floods* (Comprehensive Study, 2001) is that the Delta would act as a pool of storage, with hydraulic barriers built up by high flows from the Sacramento River and tides. Inflow from the San Joaquin River generally has much less dominance.

The downstream boundary of the lower San Joaquin River Assessment can generally be identified as the boundary of the San Joaquin River UNET model (i.e., San Joaquin River near Ship Channel, Old River at Tracy Boulevard, Middle River at Victoria Canal, and Grant Line Canal at Tracy Boulevard). Based on the observations from the 1997 flood, the modeling area of the San Joaquin River UNET model generally captures the major influence zone of the San Joaquin River flow. This determination is due in part to the limitation of DSM2 in simulating levee failure and the advantages of using a consistent tool in the lower San Joaquin River for the evaluation of project levees in the area.

## EXISTING PROJECTS THAT INFLUENCE FLOW DYNAMICS

Several existing projects and flood control facilities in the Lower San Joaquin study area affect flood flows and damages. These include Federal and private levees, bridges, flow control structures, and the facilities of the Central Valley Project (CVP) and State Water Project (SWP).

### Levees

Levees in the San Joaquin River basin are generally between 6 and 8 feet high, which is smaller than those in the Sacramento System. This is largely because the levees in the San Joaquin River Basin were designed for spring snowmelt floods with a lower return frequency than the levees in the Sacramento River Basin, which were designed for larger, winter runoff. Federal project levees in the Lower San Joaquin study area are present along the following reaches:

- the right bank of the San Joaquin from the Stanislaus River to the Stockton Deepwater Ship Channel,
- the left bank of the San Joaquin downstream from Vernalis to the Deepwater Ship Channel,
- both left and right banks of Paradise Cut, and
- Old River between the San Joaquin River and Tom Paine Slough.

Private levees are present along other waterways of the Lower San Joaquin study area, including Middle River, Old River downstream from Tom Paine Slough, and the Grant Line Canal.

### Bridges

An inventory of bridges crossing the modeled reaches of the San Joaquin River Basin was performed involving as-built plan collection and field verification. Some bridges within the basin were not included in the modeling effort because they do not significantly affect the hydraulics of the system. Bridges in the Lower San Joaquin study area are listed in Table II-4.

**TABLE II-4**
**BRIDGES IN THE LOWER SAN JOAQUIN STUDY AREA**

| Waterway | Roadway | Approximate Location |
|---|---|---|
| San Joaquin River | Airport Way<br>Union Pacific Railroad<br>Interstate 5<br>Southern Pacific Railroad<br>Bowman Road / Brandt Bridge<br>Highway 4<br>Atchison Topeka & Santa Fe RR<br>West Charter Way | Vernalis<br>Upstream from I-5<br>Upstream from Mossdale<br>Downstream from Mossdale<br>Between Mossdale & Stockton<br>Near RM 42, Stockton<br>Upstream from Burns Cutoff, Stockton<br>Near RM 40, Port of Stockton |
| Paradise Cut | Union Pacific Railroad<br>Interstate 5 – north and southbound<br>Southern Pacific Railroad<br>Paradise Road | Downstream from Paradise Dam/Weir<br>Downstream from UPRR<br>Downstream from I-5<br>Between SPRR and Old River |
| Old River | Tracy Boulevard | Downstream from Tom Paine Slough |
| Middle River | Undine Road | Near RM27, d/s from Old River |
| Grant Line Canal | Tracy Boulevard | Midway along the canal |

### Diversion and Impoundment Structures

Paradise Dam and weir, located at the mouth of Paradise Cut, controls the diversion of flood flows from the San Joaquin River to Paradise Cut. All flow entering Paradise Cut passes over the earthen weir, which was designed to operate during high flow conditions. Water present in Paradise Cut during low, summer flow conditions is a result of backwater from Old River and agricultural runoff. There are no other diversion or impoundment structures present in the Lower San Joaquin study area.

### CVP – SWP Facilities

The Harvey O. Banks Delta Pumping Plant (Banks Pumping Plant) and Tracy Pumping Plant are the primary south Delta pumping facilities used to fill the State and Federal water supply reservations in San Luis Reservoir.

Clifton Court Forebay is located adjacent to Old River near Coney Island and the terminous of the Grant Line Canal. The forebay provides water surface elevation control for Banks Pumping Plant located south of the forebay. Banks Pumping Plant is part of the State Water Project (SWP), delivering Delta water south to the South Bay Aqueduct and California Aqueduct. The eleven pumping units at the Banks Pumping Plant have a total capacity of about 10,600 cfs.

The Tracy Pumping Plant, located on a spur south of Old River, is the primary Delta pumping facility of the federal Central Valley Project (CVP). The Tracy Plant exports Delta water south to the Delta-Mendota Canal. The Tracy Pumping Plant has six pumps with a total pumping capacity of about 4,600 cfs. The Delta Cross Channel (DCC) transports water from the Sacramento River to the Tracy Pumping Plant, designed to combat salt water intrusion in the Delta and dilute local pollution from the San Joaquin. Reclamation closes the control gates of the DCC during high water to prevent flood stages in the south Delta resulting from high flow in the Sacramento River. After the flood danger passes, Reclamation opens the gates to allow Sacramento River water through to the Tracy Pumping Plant.

During the 1997 flood event, pumping at the Banks pumping plant exceeded inflows to the Clifton Court Forebay at mid-month to relieve south Delta flooding and provide emergency flood control space. This reduced water surface in the forebay to minimum operational level. The Forebay was not filled again until late January. SWP and CVP pumping during the 1997 flood event are shown in Figure II-12.

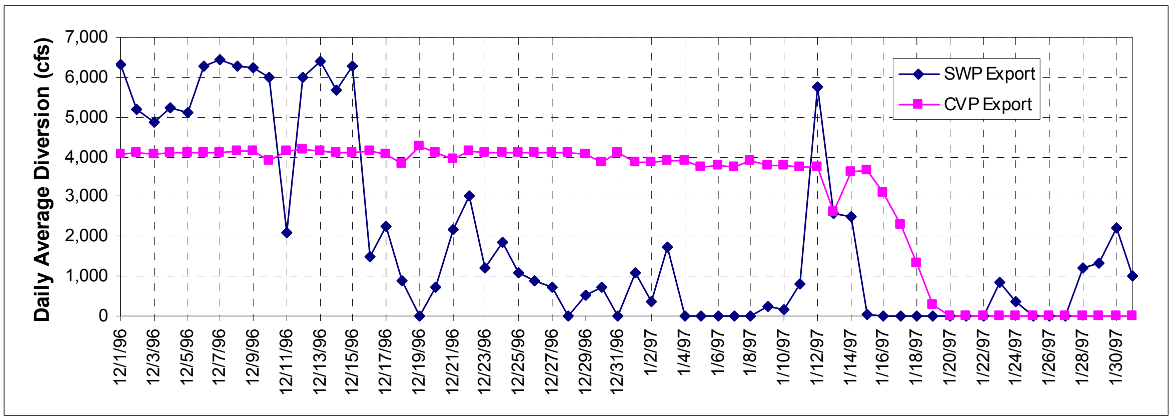



**FIGURE II-12 SWP AND CVP SOUTH DELTA DAILY AVERAGE EXPORTS DURING THE 1997 FLOOD**

As shown in Figure II-12, the larger, Banks Pumping Plant was not pumping at its peak capacity of 10,000 cfs, largely because the SWP reservation in San Luis Reservoir was full or near full. The Tracy Pumping Plant continued pumping until after the flood peak had passed. SWP and CVP operations showed localized flood benefits in the south Delta during the 1997 event.

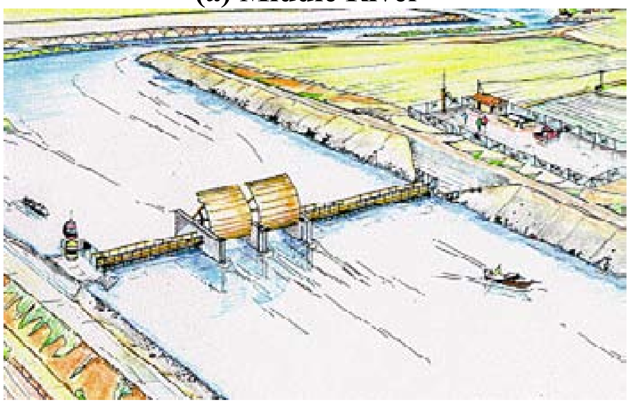
## FUTURE PROJECTS AND PROGRAMS IN THE STUDY AREA

### DWR South Delta Improvements Program

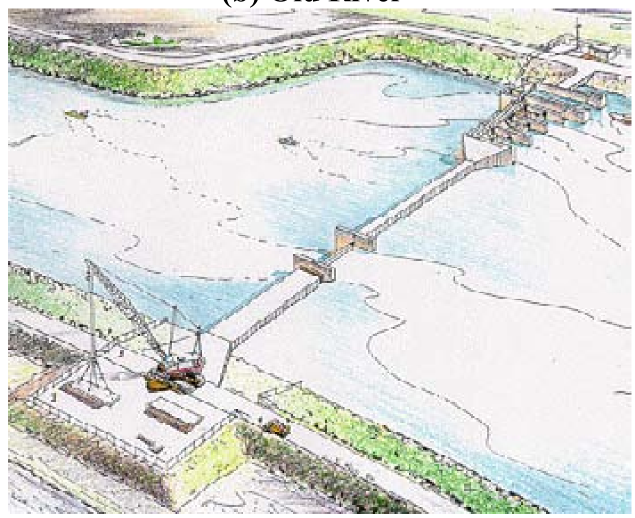
South Delta Improvements Program (SDIP) consists of the following components: flow control structures on Old River and Middle River, a fish control structure at the head of Old River, dredging of Old River, and a new intake for the Clifton Court Forebay. The purposes of SDIP are (1) to improve the reliability of existing State Water Project facilities and operations within the South Delta, while ensuring that water of adequate quantity and quality is available for diversion to beneficial use within the South Delta Water Agency's service area; and (2) to contribute to ecosystem restoration in the lower San Joaquin River and South Delta.

SDIP is an example of planned or on-going Delta projects that may affect alternative development for the Comprehensive Study. The potential impacts are from the dredging of Old River and flow control structures on both Old River and Middle River. The dredging of Old River would change channel geometry. The flow structures on Old River and Middle River are potential flow restriction points during flood conditions.

**(a) Middle River**



**(b) Old River**



*Conceptual drawings from DWR SDIP website.

**FIGURE II-2 FLOW STRUCTURES OF DWR SOUTH DELTA IMPROVEMENTS PROGRAM**

The flow control structures would have gates that raise during the flood (incoming) tide, and drop during the ebb (outgoing) tide to prevent water levels upstream of the structures from receding. The operation of the flow control structures would vary over the course of the irrigation season, but the gates would be fully open during the high water season from December to March. Both flow control structures would allow flows to pass freely during the periods of natural or regulated high flow, when water levels are maintained without the need for flow control.

### Delta Ecosystem Restoration

Ecosystem restoration in the Delta is a component of various ongoing projects and programs. The Comprehensive Study is coordinating with all major programs, including CALFED. Representatives from the California Department of Fish and Game were consulted regarding ongoing CALFED planning in the Delta and briefed on the progress and intention of the Comprehensive Study. These representatives indicated that major dredging in Middle River should be avoided for the preservation of fishery habitat. Any actions undertaken by the Comprehensive Study that would adversely affect the ecosystem in the Delta would require mitigation. For example, the recent dredging activity in the Old River under the DWR SDIP required a purchase of 18 acres of mitigation credit at the Kimball Island Mitigation Bank to prevent net loss of habitat.

# CHAPTER III

# EXISTING SYSTEM HYDRODYNAMIC MODELING

## EXISTING HYDRODYNAMIC MODELS

Two hydrodynamic models are used in this study: SJRUNET and DSM2. Both models are one-dimensional, unsteady, hydrodynamic models. SJRUNET was used for alternative development and analysis by the Comprehensive Study, and the DSM2 was evaluated for use in assessing impacts to the Delta resulting from the alternative improvements studied by the comprehensive study

### San Joaquin River UNET model

SJRUNET was developed by the Comprehensive Study for the development and evaluation of comprehensive master plans for flood damage reduction. The San Joaquin River UNET model covers the mainstem of the San Joaquin River from Friant Dam downstream to Stockton, and its major tributaries below their controlling reservoirs. Input hydrologies at the upstream boundaries of the model were developed through hydrologic simulations of upstream watersheds and controlling reservoirs. The downstream boundaries of SJRUNET are the following locations: San Joaquin River at Burns Cutoff, Old River at Tracy Boulevard, Middle River at Highway 4, and Grant Line Canal at Tracy Boulevard.

A detailed description of SJRUNET is available in *Appendix D: Hydraulic Technical Documentation, F4 In-Progress Review Report*, (COE, October 2001.) The development of hydrologic data for the study is described in *Appendix B: Synthetic Hydrology Documentation, F4 In-Progress Review Report*, (COE, October 2001).

### Delta Simulation Model II

DSM2 is a river, estuary, and land modeling system. The model includes modules for hydrodynamic and water quality calculations. The hydrodynamics module calculates stages, flows, and velocities in rivers and tidal estuaries, given boundary stages, rim flows, and internal flows (sources and sinks). The quality module calculates water quality concentrations in rivers and tidal estuaries, given previously calculated flows and stages from DSM2-Hydro, boundary concentrations, and internal sources and sinks. The modeling area of DSM2 includes all areas in the Sacramento-San Joaquin Delta. At the end of year 2000, DWR has completed a re-calibration for DSM2. The re-calibration was needed to incorporate new irregular channel geometry and other schematic changes in the model.

DSM2 has flow boundaries at the following locations: San Joaquin River at Vernalis, Sacramento River at I Street, Yolo Bypass at Shag Slough, Cosumnes River at Franklin Road, Mokelumne River at Franklin Road, Calaveras River at San Joaquin River. At the downstream end, DSM2 uses the tide stages at Martinez as the downstream boundary conditions. DSM2 also incorporates the consumptive use in the Delta, and CVP and SWP exports.

### *Application to Flood Simulations*

The original application of DSM2 is under normal and low flow conditions, i.e., non-flooding conditions. Because DSM2 was identified by the Study Team as a potential model for use in evaluating project impacts in the Delta, DWR staff has conducted simulation runs for the 1997 flood. The simulation results provided by DWR staff is attached as Appendix A. DWR staff reached the following conclusions:

- The historical records of San Joaquin River flow at Vernalis after January 4, 1997 may be erroneous. The San Joaquin River flow at Vernalis serves as a boundary condition in DSM2 hydraulic model. The flow peak may be overstated and the third flood peak appears to be missing in the records. As a result, the simulated river stages show significant discrepancies from the historic records at many locations in the south and central Delta.
- The simulation results using the existing DSM2 model are satisfactory after the data anomaly of San Joaquin River flow at Vernalis is removed. A regression analysis, which correlates the San Joaquin River flow at Vernalis and the river stage of San Joaquin River at Brandt Bridge, was used to synthesize a possible hydrograph of the San Joaquin River at Vernalis after January 4. The adjusted San Joaquin River flows at Vernalis are obtained by using the regression formula, the historical records of river stage at Brandt, and the average tide. The synthesized hydrograph of San Joaquin River at Vernalis was then used as the boundary condition in the model simulation. The results show significant improvements in river stage prediction in the Delta.

The existing DSM2, which was calibrated to normal flow conditions, is adequate for use by the Comprehensive Study for comparative analyses. The results of DSM2 simulation for the 1997 flood are satisfactory after the data anomaly in the San Joaquin River flow at Vernalis is removed.

### *Limitations of DSM2 in Flood Simulations*

As previously discussed, DSM2 was not developed for flood simulation. The topography included in the model is sufficient to contain low-flow, but may not extend to the existing top of levee elevation in all areas. In addition, DSM2 is not capable of simulating levee breaks or overtopping. When water surfaces exceed the available geometry in a cross section, the model contains all flow within assumed vertical “walls” on both sides of the channel. Furthermore, DSM2 does not have the capability of simulating complex bridge hydraulics. These limitations would result in evaluation of flood events inconsistent to those in the comprehensive study.

## MODIFIED MODELS FOR STUDY AREA

### San Joaquin River UNET Model

The SJRUNET used in this study is consistent to that used in other plan formulation efforts in the Comprehensive Study. Channel geometry was modified, as necessary, to develop and evaluate alternative scenarios.

### *Upstream Hydrology*

Upstream hydrology used for these analyses was synthetic storm data developed by the Comprehensive Study. Detailed information on the development of this data can be found in *Appendix B – Synthetic Hydrology Documentation, F4 In-Progress Review*, September 2001. Specific storm centerings were developed for the Lower San Joaquin Study area.

### *Upstream Improvement*

Because the Comprehensive Study is still in the progress of developing master plans, flow data used in analyses for the Lower San Joaquin study area does not consider the hydraulic impact of possible measures upstream from the study area. Potential upstream modifications could include reservoir reoperation, conveyance improvements, or other measures that would change peak flood flows and stages in the study area. Consequently, the hydraulic analysis of potential improvement scenarios in the study area will use two sets of hydraulic input: baseline, and "infinite channel." The baseline input approximates existing conditions and levee integrity, including levee breaks and floodplain storage. The infinite channel input assumes that all flow in the system is contained within the channels, resulting in higher flows reaching the Delta. Together, the baseline and infinite channel inputs bound a range of potential flow conditions in the study area.

### *Downstream Boundary Conditions*

The downstream boundaries of SJRUNET are the following locations: San Joaquin River at Burns Cutoff, Old River at Tracy Boulevard, Middle River at Highway 4, and Grant Line Canal at Tracy Boulevard. Project levees in the south Delta are included in this modeling area. The downstream boundary conditions currently used in the SJRUNT are rating curves developed largely by records of the 1997 flood. See *Hydraulic Technical Documentation*, *In-Progress Review Report: Appendix C* for details.

## Delta Simulation Model II

Although UNET and DSM2 are both one-dimensional hydrodynamic models, they have very different capabilities in terms of simulating floods. SJRUNET simulates the San Joaquin River basin under flooding conditions with potential levee breaks and off-channel storage. DSM2 does not have the capability of simulating levee breaks or off-channel storage. Vertical walls with infinite height on both sides of the channel are assumed in DSM2 when more capacity is needed to pass flows. This limitation restricts the use of DSM2 in determining the potential needs for levee improvements in the Delta. The two models overlap along several reaches; however, they would not produce similar results in these areas due to the model differences. For these reasons, the San Joaquin UNET model and DSM2 used for this study were modified to reconcile some of the differences between the models and their results.

### *Model Reduction*

The modeled area of DSM2 was reduced to cover only those areas in the Delta outside of SJRUNET model. This model reduction is necessary because DSM2 has limitations in simulating levee failures and hydrodynamics around bridges. In addition, SJRUNET has more detailed channel geometry and levee information than DSM2, making its use more appropriate in overlap areas and more consistent with other ongoing modeling efforts.

The upstream boundaries of the reduced DSM2 are the downstream boundaries of the UNET models (both Sacramento and San Joaquin): Sacramento River at Collinsville, downstream end of Three Mile Slough, the downstream end of Georgiana Slough, San Joaquin River at Burns Cutoff, Old River at Tracy Boulevard, Middle River at Highway 4 and Grand Line Canal at Tracy Boulevard. The original upstream boundaries for eastside streams remain unchanged, and the downstream boundary remains at Martinez.

### *UNET Hydrology Handoff Points*

Output from the downstream ends of the UNET model was used as input to the DSM2 model. The output/input was in the form of hydrographs. UNET-DSM2 handoff points were located on the following waterways:

- San Joaquin River
- Middle River
- Grant Line Canal
- Old River

### *Downstream Stage Boundary Condition at Martinez*

One of the most challenging tasks for DSM2 simulations is the determination of a proper downstream boundary condition at Martinez for synthetic storm events. As mentioned in previous chapters, the occurrence of tides is governed by the planetary movements of the sun, the moon, and the earth. The frequency analysis often used for surface water hydrology is not applicable. Several possible downstream boundary conditions have been suggested including the long-term average tidal ranges, and the historical tidal ranges in the 1997 Flood.

After examining the historical tidal ranges and the net Delta outflow during flooding conditions, DWR suggested that the historical tidal ranges in the 1997 Flood is representative and can be applied to all flooding events currently considered by the Comprehensive Study. The conclusion was from a net Delta outflow analysis conducted by DWR. This analysis focused on possible stage variation at Martinez during different flood events. The net Delta outflows (flows at Martinez) that are greater than 200,000 cfs were correlated to the 14-day running averages of the stage at Martinez. The regression analysis suggests that the difference of 14-day running average stages at Martinez for a 100-year and a 500-year event is less than 2 inches. Therefore, the errors introduced by using the historical tidal ranges in the 1997 Flood as DSM2's downstream boundary conditions for all Comprehensive Study simulations are insignificant. The DWR memorandum that summarizes the findings is provided in Attachment B. As discussed in the previous chapter, the tidal ranges in the 1997 Flood were enhanced by the parallax effect and were at the seasonal height; however, they are not out of ordinary since tidal ranges of similar magnitudes have been observed in 1995.

The simulated storms used in the Comprehensive Study start at a synthetic January 1900 time frame to avoid confusion with actual historical records. The assumed hydrology distribution, upstream reservoir operations and levee failure scenarios create peak flows from the Sacramento

River and the San Joaquin River entering into the Delta around mid January and late January, respectively. During the 1997 Flood, the flood peaks arrived on January 3 and 5, respectively. DWR has determined that the tidal ranges of the 1997 Flood are adequate for the DSM2 simulations for the Comprehensive Study. However, the timing for neap and spring tides need further evaluation. The new moon in the 1997 Flood occurred around January 9. Therefore, it is necessary to delay the 1997 tidal ranges to match the neap tide to the peak flow from the Sacramento River so that the downstream boundary conditions become more meaningful.

Detailed discussions regarding the tides in the Delta and the comparison of the 1997 flood and historical records can be found in *Existing Hydrodynamic Conditions in the Delta during Floods* (COE, September 2001).

#### *Other Assumptions*

Other assumptions used in the DSM2 simulations for the Comprehensive Study include:

- Consumptive use in the Delta is ignored due to its small magnitude relative to flood flows.
- The DCC is closed, consistent with current operation.
- CVP-SWP south Delta pumping and all other export diversions are stopped because it is difficult to speculate the level of storage in the San Luis Reservoir. Assuming no pumping of excess water will result in conservative estimates of flooding in the south Delta.
- All temporary flow barriers in the Delta waterways are removed, consistent with current practice. No permanent flow barriers are assumed.

Based on the discussions presented in the previous chapters, these assumptions are considered adequate and reasonable for the purposes of the Comprehensive Study.

### Recommendations for Use and Interpretation of UNET and DSM2 Results

Computer models are simplified versions of physical environments. Due to the simplification, model assumptions often govern the potential uses of a model. The results may be misleading if the model assumptions are not used as guidelines in the interpretation. As discussed previously, the UNET and DSM2 models were developed independently using different geometric data and were intended for different purposes. Consequently, recommendations for model usage and results interpretation are summarized as follows.

- Scenarios can be compared on a relative basis, within the corresponding results from DSM2 or within those from UNET to address the potential impacts of measures for flood damage reduction.
- The flow stages predicted by DSM2 and UNET should not be directly compared, even if the simulations assume no levee breaks (UNET) or exceedence in physical channel capacity (DSM2) in the vicinity of model boundaries. This is due to differences in channel geometry detail between the models.
- Levee breaks and the associated level of protection cannot be addressed by DSM2 because the model assumes ‘infinite channel’ conditions (no out-of-bank flow). While DSM2 may indicate the need for hydraulic mitigation, this model is not the proper tool for evaluating mitigation measures or mitigation alternatives in the Delta.

## BASELINE CONDITION

The baseline condition should be discussed in a larger context of the entire Delta to better illustrate the complexity of Delta hydrodynamics and the impacts to the lower San Joaquin River assessment. *Existing Hydrodynamic Conditions in the Delta during Flood* (COE, September 2001) reports a detailed discussion of the baseline condition that includes the baseline hydrologic information on the Sacramento River inflow, San Joaquin River inflow, and eastside streams. A brief summary is provided in the following.

The Delta is the converging point of tides and inflows from Sacramento River, San Joaquin River and eastside streams. The stage at a location in the Delta at any time is the result of balancing the currents introduced by these factors. Therefore, the discussion of the hydrodynamic conditions in the Delta is often found to be case specific although some generalization is possible.

In the baseline conditions, the San Joaquin River peak inflow arrives at the Delta much later than the Sacramento River peak. In addition, inflows from the eastside streams are in a different pattern than those from the Sacramento and San Joaquin rivers. This simulated condition helps to delineate the relative importance of these factors in the determination of river stage in the Delta. The domination of Sacramento River flows and the tidal ranges at Martinez are observed in the comparison of 25-hour moving averages of river stage in the Delta. The stages in the area from Martinez to Jersey Point are largely controlled by the tidal ranges at Martinez and the Sacramento River flow at Collinsville. To the east, the stages in the central Delta are highly correlated to those of the Georgiana Slough and Three Mile Slough. On the other hand, inflows to the south Delta area have only a limited area of influence in terms of water stage. The influence of San Joaquin River inflows dissipates significantly several miles downstream from the model boundaries near the Clifton Court Forebay, although the influence is more prominent when Delta and San Joaquin River storm centerings are considered. The eastside streams show no influence in any of the modeled storm events.

Although variations in magnitude exist, the Delta hydrodynamics simulated in all baseline scenarios are similar. The high stages caused by Georgiana Slough inflows clearly become a major hydraulic barrier for river flows in San Joaquin River and Middle River. The locations of Sacramento River inflows and the Martinez tidal gage are aligned at the north side of the modeling area, establishing the hydraulic grade line that controls the simulated Delta outflows. The peak flows from Sacramento River near January 20 and the concurrent high tides created a high stage condition that is prevalent in the Delta. The south Delta inflows during the high tide condition flow from the Old River to the Middle River and San Joaquin River through the Victoria Canal. On January 25, although the high flows from Sacramento River sustains, the high tide has greatly recessed. Therefore, more flows can be released through Martinez to the ocean, alleviating the high stage condition in the Delta. It is noted that simulated stages in Georgiana Slough are consistently higher than those of nearby locations, forcing more flows from the San Joaquin River into Old River. The flows in Old River increases significantly after the spring tide passes and south Delta inflows to the Delta increases in the later part of the simulation period.

# CHAPTER IV

# FUNDAMENTAL FLOOD PROBLEM IN STUDY AREA

Flow in the San Joaquin River at Vernalis is largely influenced by flood control reservoirs on the Tuolumne and Stanislaus Rivers. The sediment load in the San Joaquin system is significant, and sedimentation through out the system has diminished the overall flow capacity. At the downstream limits of the existing flood control project, the system appears to be undersized and does not extend far enough into the Delta to pass design flows adequately. In addition, the flood control system was designed largely to protect agricultural lands, rather than the residential, commercial, and industrial development that has occurred in the Stockton and Lathrop areas during recent years. With the exception of the greater Stockton area, land use in the study area is primarily agricultural with scattered rural development and small communities. Agriculture in this area is generally limited to field crops, tomatoes, pasture, and miscellaneous truck crops.

The *Post-Flood Assessment* (COE, March 1999) reported that the San Joaquin River flood control levee and channel system lacks the capacity to convey design flood flows. Design flood flows are those defined by the Department of Water Resources in May 1985. The channel design flow downstream of Vernalis is 52,000 cfs; however, levees begin to fail or are overtopped when flows exceed 40,000 cfs near Vernalis. The FEMA 100-year discharge at Vernalis (RM 72.6) is 79,000 cfs. The 1998 revised 100-year discharge is 50,000 cfs, reflecting the impact of upstream levee breaks during high flows.

In contrast, summer flows into this area are very low, as upstream water supply reservoirs often capture the majority of summer runoff from the upper watersheds. During summer months, reaches in the Delta are often stagnant and may experience backflow from tide cycles. Low summer flows, and the resulting saltwater intrusion, are a concern in terms of the ecosystem restoration potential of the study area.

## 1997 FLOOD

Table IV-1 summarizes areas affected by flooding within the Lower San Joaquin study area during the 1997 flood event. The extent of flooding during the 1997 event is illustrated in Figures IV-1 and IV-2 in *Post Flood Assessment* (COE, March 1999).

**TABLE IV-1**

**AREAS IN THE SOUTH AFFECTED BY FLOODING DURING 1997 RAIN FLOOD**

| Stream | Area | Description |
|---|---|---|
| San Joaquin River/ Stanislaus River | RD 2064 (River Junction) | East levee failed in two places |
| San Joaquin River | RD 2075 (McMullin Ranch) | East levee failed in three places |
| San Joaquin River | RD 2094 (Walthall Tract) | East levee breached in four places; water from RD 2094 break flooded RD 2096 |
| San Joaquin River | RD 2096 (Weatherbee Lake) | East levee failed; mouth of Walthall Slough |
| Paradise Cut | RD 2107 (Mossdale Tract) | East levee break floods RDs 2062 (Stuart Track) and 2107 (Mossdale Track) |
| Paradise Cut | RD 2095 (Paradise Junction) | Partially inundated when south levee failed |
| Paradise Cut | RD 2058 (Peecaredo District) | Partially flooded by overflow of unleveed Tom Paine Slough |
| Prospect Island | Prospect Island | Multiple levee breaks |

Source: COE, *Post Flood Assessment*, 1999, Table 5-34

## AREAS SUBJECT TO FLOOD DAMAGE

Areas adjacent to the San Joaquin and its distributaries that are protected by levees are at risk of flooding in the event of levee failure or overtopping. Many islands in the south Delta are near or below sea level, increasing their flood risk. In addition, several tributaries to the San Joaquin near the Stockton/Lathrop area could compound the flood risk, including the Calaveras River, Mormon Slough, Little Johns Creek, Duck Creek, and Lone Tree Creek.

Several areas are noted below that may have a higher risk of flood damages. The areas noted do not represent all areas in the Lower San Joaquin that could experience flooding, but they have been determined to be at high risk due to repeated flooding within the last century or potential hazards to public safety.

### Eastside of San Joaquin River – Vernalis to Old River

A levee breached near Vernalis during the 1983 flood event, inundating about 6,000 acres. In 1997, the right bank (east) levee of the San Joaquin failed in numerous locations downstream from Vernalis, flooding Reclamation Districts (RD's) 2064, 2075, 2094, and 2096. Out-of-channel flow was estimated at about 48,800 cfs during the peak of the 1997 flood *Post-Flood Assessment,* (COE, March 1999).

This area is primarily in agriculture, with scattered rural development. Levees are maintained by several reclamation districts and are present both parallel and perpendicular to the San Joaquin. This area is noted because the land generally slopes away from the river and flood flows could cover a large floodplain, extending past Manteca. In addition, the advertised design capacities in this reach are estimated to be insufficient to carry large flood events.

### Stockton / Lathrop Urban Area

It has been speculated that the greater Stockton area, including neighboring Lathrop, would have flooded in 1997 had levee breaks downstream from Vernalis not released pressure on levees and dropped river stage in Stockton. Stockton is subject to additional flood risk from the Calaveras River, which passes through the town from the east. This area is noted because it could experience significant flood damages to heavy residential, commercial, and industrial development and because the potential threat to public safety is high.

### Stewart Tract

Stewart Tract is bound by Paradise Cut to the west, the San Joaquin River to the east, and Old River to the North. Stewart Tract experienced flooding in 1938, 1950, and 1997. In 1997, flooding was caused by levee breaks on the right bank (east) of Paradise Cut and flooding occurred in RD 2107 and RD 2095. Currently, Stewart Tract is primarily in agriculture, with scattered rural development. This area is noted because of previous flooding and because dense residential and commercial development has been proposed on Stewart Tract by private interests.

# CHAPTER V

# POTENTIAL FLOOD DAMAGE REDUCTION AND ECOSYSTEM RESTORATION MEASURES

The purpose of the Lower San Joaquin Assessment is to evaluate hydrodynamic conditions in the area and use this knowledge to identify effective flood damage reduction measures and associated ecosystem values. The previous chapters of this report detailed the existing conditions in the study area and the hydraulic models that have been developed for use in this complex area. This chapter will describe the various flood damage reduction and ecosystem restoration measures that have been identified in this area, and the screening process used to evaluate the effectiveness of these measures. The most promising measures will be retained for further evaluation and use in alternative master plans.

*Appendix E – Measure Screening Report, F4 In-Progress Review Report*, (COE, October 2001), contains a discussion of the screening and evaluation of the hundreds of flood damage reduction and related ecosystem restoration measures that have been identified by the Comprehensive Study. This chapter includes a summary of the evaluation criteria used in the measure screening process, screening results, and a discussion of specific measures identified within the Lower San Joaquin study area.

## PLANNING OBJECTIVES AND FORMULATION

Screening is the process for comparing measures against performance criteria. The purpose of the measure screening process is to identify measures that are superior in terms of their performance and/or financial investment and may be combined with other measures to form alternative master plans. The screening process also identifies measures that do not meet the performance standards of the project or have unacceptable environmental, socio-economic, or other impacts.

Performance criteria developed by the Comprehensive Study were divided into three categories: general criteria, flood damage reduction criteria, and ecosystem restoration criteria.

### General Criteria

**Cost Effectiveness** – Cost considerations include initial (capital) costs, long-term operation and maintenance, impacts to existing infrastructure (transportation, utilities, etc), and other cost factors. Measures that have high costs in relation to their effectiveness to meet study objectives are given low to very low rankings.

**Acceptability** – This criterion accounts for measure acceptability from both government agencies and local stakeholders, compatibility with existing general plans (land use, proposed projects, etc), and potential for detrimental impacts to third parties or redirected impacts. Measures that have widespread support and/or have no redirected impacts are ranked as high or very high.

**Ability to Combine with Other Measures** – This criterion accounts for a measure's ability to be combined with other proposed measures to form a complete plan. Measures that do not preclude the use of other measures or limit the planning process are ranked as high or very high.

**Ability to Combine with Other Programs** – This criterion accounts for a measure's ability to be integrated with other current and proposed programs, such as CALFED, San Joaquin River Management Plan (SJRMP), and Central Valley Project Improvement Act (CVPIA). Measures that conflict with the objectives of other programs are ranked as low or very low.

**Affect on Existing Water Use** – This criterion accounts for impacts to surface and groundwater supplies, hydropower, groundwater recharge, water quality, and agricultural and municipal uses. Measures that increase water supply, water quality, and/or hydropower are ranked as high or very high.

**Cultural/Social Resources** – This criterion accounts for impacts on recreational opportunities, social and cultural resources or values, and educational opportunities. Measures that increase recreational opportunities or have a positive impact on cultural/social resources are ranked high or very high.

### Flood Damage Reduction Criteria

**Effect on Peak Flow** – This criterion accounts for reductions or increases in peak flood flows within the system, including downstream hydraulic impacts. Measures that reduce peak flows are ranked as high or very high.

**Effect on Peak Stage** – This criterion accounts for reductions or increases in peak flood stage within the system. Measures that increase peak stage without increasing capacity are rated as very low or low.

**Effect on High Flow Duration** – This criterion accounts for impacts resulting from prolonged high stage levels on levees and other system features. Measures that increase or prolong high stages, making levees more susceptible to failure, are ranked as very low or low.

**System Reliability** – This criterion accounts for the affects on the long-term reliability of the flood management system, taking into account long-term O&M requirements and risk of failure due to unanticipated actions. Measures that increase flood control reliability are ranked as high or very high.

**Flood Damage Reduction Effectiveness** – This criterion specifically addresses the flood damage reduction benefits to protected areas or residual risk. Measures that are highly effective at reducing flood damages and/or reducing residual risk are ranked as high or very high.

### Ecosystem Restoration Criteria

**Habitat Quantity and Quality** – This criterion includes impacts to the quantity and quality of terrestrial floodplain habitat and aquatic habitat. Measures that increase the acreage of habitat and/or improve habitat quality are ranked as high or very high.

**Contribution to Self-sustaining Geomorphic Processes** – This criterion includes contributions to support and improve natural geomorphological processes such as natural degradation and aggradation processes, meandering, etc. Measures that enhance these processes are ranked as high or very high.

**<u>Preservation of Agriculture and its Ecological Value</u>** – This criterion includes contributions by agricultural lands to the preservation of wildlife habitat and accounts for their ecological values. Measures that reduce the acreage of land in agricultural production and/or diminish its ecological value are ranked as low or very low.

## MEASURES CONSIDERED IN THE LOWER SAN JOAQUIN

A broad range of potential measures to reduce flood damages and restore related ecosystem values in the Central Valley has been identified by the Comprehensive Study. These measures can be organized into three categories: storage, conveyance, and floodplain management (non-structural/non-traditional). For screening purposes, storage and conveyance measures can be evaluated on a geographical basis (specific to a location or reach), whereas floodplain management measures are typically system-wide (requiring legislation or other institutional changes). Discussions in the following sections are limited to the measures identified in the Lower San Joaquin study area. The study is generally delineated by the following locations: the confluence of San Joaquin River and Stanislaus River, San Joaquin River near Stockton, Middle River near Victoria Canal, Old River near Tracy Boulevard, and Grant Line Canal near Tracy Boulevard.

### Storage Measures

Storage measures can be further categorized into four methods of achieving or improving flood control:

- Measures that revise flood control operations,
- Measures that increase flood control allocation (with no structural modifications),
- Measures that increase foothill and upper-watershed flood storage, and
- Measures that increase floodplain storage.

The first three methods listed above do not apply to the Lower San Joaquin study area, as there are no major flood control reservoirs or opportunities to construct a major reservoir in the area. Floodplain storage, also termed transient storage, is employed during storm events to attenuate peak flood flows. Water would be diverted into temporary storage locations to prevent damages downstream (i.e. channel erosion, levee failure, etc.). Immediately following the storm event, the transient storage area would be evacuated and made available for the next storm event. This differs from off-stream storage, where water is stored and later released for water supply purposes and may remain at that location for a longer period of time.

No existing transient storage facilities are located within the Lower San Joaquin study area. Development of a new transient storage area would involve acquiring lands or easements adjacent to the San Joaquin or a major distributary thereof. The area would need to be disconnected from the river and bound by either existing topography or levees such that stored water would not travel overland and damage adjacent areas. The storage area would receive water when flood flows reached a certain magnitude or stage, likely via a weir. The topography and hydrography of the Lower San Joaquin study area also make it unsuitable for transient storage. In addition, it would be difficult to acquire a large enough tract of land in the study area to store a significant amount of the flood peak. Therefore, no floodplain storage measures were considered in the Lower San Joaquin study area.

**Conveyance Measures**

Conveyance measures can be further categorized into three methods of improving the flood control conveyance system:

- Measures that modify capacity or reliability of the existing system,
- Measures that enlarge or expand the existing system, and
- Measures that restore habitat associated with the conveyance system.

Measures that modify the capacity or reliability of the existing system can include clearing and snagging of channel vegetation; dredging and sediment removal; modification of weirs; reduction of constrictions or removal of hard points (such as riprap); strengthening levees, and channelization (construction of new channels within the floodplains). Measures that enlarge or expand the existing system can include raising or realigning existing levees, enlarging flood bypasses or constructing new bypasses, and constructing new levees. Measures that restore habitat associated with the conveyance system address the restoration of riparian, wetland, and upland habitat through actions such as planting and ground re-contouring, removal or non-native species, vegetation restoration, or acquisition of conservation easements.

The following potential conveyance measures were identified in the Lower San Joaquin study area, and are organized by the conveyance categories described above. The results are summarized in Table V-1, following the discussion.

***Measures that Modify Capacity or Reliability of the Existing System***

Clearing and snagging of vegetation would not be effective in the larger flood channels in the study area (e.g. the San Joaquin River) because there is not enough vegetation to adversely affect conveyance. Smaller channels, such as Old River, do not have a large enough conveyance capacity when compared with the magnitude of flow in a large flood event to warrant the cost and environmental consequences of this measure. This measure would disturb valuable aquatic habitat that is an important component to ecosystem restoration programs in the area. While localized benefits may be realized, the distributary nature of the Lower San Joaquin River study area would diminish any widespread benefits by re-distributing the floodwater downstream from the improved channel area. The Comprehensive Study is focuses on identifying comprehensive measures that contribute to overall flood management system, rather than measures that provide localized benefits. This measure was not retained.

Dredging and sediment removal could have a beneficial impact on channel capacity, particularly in the smaller distributary channels of the San Joaquin. For example, excavation in Middle River to remove sediment that has been deposited in this channel could increase flow capacity and reduce stage and backwater conditions on the lower San Joaquin River, contributing to flood damage reduction throughout the area. This measure was retained for further consideration.

Hardpoints, such as riprap, may be removed in order to provide opportunities for riparian habitat restoration. This measure may require active planting of appropriate native species to aid in the stabilization of river and levee banks. This measure may not be applicable in areas prone to high velocity flows, such as tight bends or deep, swift-flowing channels. The removal of hardpoints was retained for further consideration. Constrictions, which may occur at bridges or locations where channel geometry restricts flow, may be removed to increase channel conveyance capacity. One constriction was identified in the study area, along Paradise Cut near the Interstate 5 crossing. This approximately 1-mile long section of the Paradise Cut is narrow in comparison to the remainder of the cut and has three bridge crossings: I-5 (north and south bound), HWY 205, and the Union Pacific Railroad (UPRR). This area has constricted flow and caused backwater conditions during past flood events, and levee failures on Stewart Tract have resulted. The removal of constrictions was retained for further study.

Paradise Cut Weir controls flows from the San Joaquin River to Paradise Cute, which in turn flows into Old River. Modification of this weir, either to widen the weir or change the weir elevation, could benefit stage and backwater conditions on the lower San Joaquin River and contribute to flood damage reduction throughout the area. This measure may entail additional capacity improvements along Paradise Cut (levee strengthening, channel widening, removal of constrictions, etc). Weir modification at Paradise Cut was retained for further consideration.

The reliability of the levees in the study area varies significantly. Many levees are in poor condition and would require strengthening to safely pass design flood flows or higher project flows. Strengthening levees was retained for further consideration, where necessary.

No opportunities for channelization (construction of new flood channels in the floodplain) were identified in this reach. This measure is not applicable.

#### *Measures that Enlarge or Expand the Existing System*

Existing levees in the study area may not be able to pass anticipated flood flows safely. Raising the crown elevation of existing levees could allow these levees to pass design flows or higher flows, and this measure was retained. Realignment of existing levees would increase the flow area of the flood control channels in this reach, making it possible to remove constrictions or convey larger flows. Existing levees immediately adjacent to the waterway would either be degraded or left in-place without maintenance (allowed to degrade over time). Levee realignment would require the acquisition of land in fee or acquisition of flowage easements. This measure is less applicable to levees that bound smaller islands, as the amount of land protected by these levees is already relatively small. The realignment of levees along Paradise Cut and the lower San Joaquin River was retained for further consideration.

The construction of new levees, such as back-up levees, may be applicable in the study area. Back-up levees would allow agriculture or other appropriate activities to occur in the floodplain while protecting residences and other high-value areas from large flood events. The construction of back-up levees may require the acquisition of flowage easements or other mechanisms to establish proper guidelines for the use of lands within the backup levees, and would require local landowner support. Lands within the back-up levees would be subject to periodic flooding from lower-frequency flood events. Both existing and back-up levees would require regular maintenance. The construction of back-up levees was retained for further consideration.

No opportunities to construct a new flood bypass were identified in the study area. This area is already highly channelized, and the construction of a new bypass would not significantly affect the passage of flood flows through the area. This measure was not retained.

### *Measures that Restore Habitat Associated with the System*

The Lower San Joaquin study area contains numerous opportunities for ecosystem restoration through the establishment of healthy habitat. This measure can accomplish restoration goals through levee modifications, realignments of existing levees, or other structural modifications. Restoration of vegetation within the conveyance system can reduce flow capacity, but can also improve the reliability of the system by stabilizing banks and reducing erosion. Vegetation is also an important part of restoring aquatic habitat in the Delta. No specific areas have been identified for the application of this measure. This measure has been retained for further consideration.

### *Summary of Conveyance Measures Identified*

Table V-1 summarizes the evaluation results for conveyance measures within the study area. The table provides a relative comparison of each type of applicable conveyance measure, utilizing the screening criteria previously identified.

# TABLE V-1

## EVALUATION OF CONVEYANCE MEASURES IN THE LOWER SAN JOAQUIN STUDY AREA

| Measure | General Criteria | | | | | | | Flood Damage Reduction Criteria | | | | | Ecosystem Restoration Criteria | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cost Effectiveness | Acceptability | Ability to Combine with Other Measures | Ability to Integrate with Other Programs | Effect on Existing Water Uses | Cultural/ Social Resources | Geographic Extent of Benefits | Effect on Peak Flow | Effect on Peak Stage | Effect on "High" Flow Duration | System Reliability | FDR Effectiveness | Habitat Quantity/ Quality | Self-Sustaining Geomorphological Processes | Ecological Diversity | Preservation of Agriculture and its Ecological Value |
| **Measures that Modify Capacity or Reliability of the Existing System** | | | | | | | | | | | | | | | | |
| Clearing and Snagging | low | low | low | very low | med | low | very low | very low | low | very low | low | very low | very low | very low | very low | low |
| Dredging/Sediment Removal | med | med | med | very low | med | med | low | low | high | low | med | med | low | low | low | med |
| Reduce Constrictions and Hard Points | med | med | high | high | med | med | med | med | med | med | med | med | high | med | high | med |
| Weir Modification – *Paradise Cut Weir* | med | high | high | low | med | med | high | med | high | med | high | med | med | low | med | med |
| Strengthen Levees | med | med | med | low | med | med | med | med | med | med | very high | med | med | low | med | high |
| Channelization | Not Applicable in this Reach | | | | | | | | | | | | | | | |
| **Measures that Enlarge or Expand the Existing System** | | | | | | | | | | | | | | | | |
| Raise Existing Levees | med | med | med | low | med | med | med | med | med | med | very high | med | med | low | med | high |
| Realign Existing Levees | med | med | high | high | med | med | med | med | very high | med | very high | med | high | high | high | high |
| Construct New Levees – *Back-up Levees* | med | med | med | med | med | med | med | med | med | med | very high | med | med | med | med | med |
| Construct New Bypass | Not Applicable in this Reach | | | | | | | | | | | | | | | |
| **Measures that Restore Habitat Associated with the System** | | | | | | | | | | | | | | | | |
| Restore Riparian, Wetland and Upland Habitat | med | med | high | very high | med | med | high | med | low | med | low | low | very high | med | very high | low |

Key:

- (shaded) Measure retained for further consideration
- (unshaded) Measure not retained for further consideration, or measure not applicable in this reach

**Floodplain Management Measures**

Floodplain management measures, often termed non-structural / non-traditional measures, seek to reduce flood damages via institutional changes or changes in the way people think about flood risk, rather than physical changes to the flood control system itself. Floodplain management measures can be categorized into four methods of reducing flood damages and flood risk:

- Measures that modify susceptibility to flood damage,
- Measures that improve emergency planning, evacuation, and post-flood recovery
- Measures that increase awareness and understanding of flood risk, and
- Measures that integrate flood planning in land use decisions.

Measures that modify susceptibility to flood damage include flood proofing and relocating structures, obtaining flowage easements, and pre-flood hazard mitigation programs. Flood proofing prevents or reduces damages to individual facilities or structures located in the flood zone, allowing the continued use of the structure. Flood proofing can be accomplished in several ways, by raising the structure, construction flood barriers (such as floodwalls or berms), dry flood proofing (preventing water from entering the structure), or wet flood proofing (allowing water to enter the structure, but reducing damages). Structure relocation may be appropriate when flood proofing or other measures are not effective in reducing damages. Flowage easements allow for the temporary storage or passage of floodwaters such that the likelihood of economic damages or loss of life is minimized. Land where a flowage easement is secured may still be used for purposes such as agriculture, but an agreement would be put in place allowing the property to be periodically flooded. Pre-flood hazard mitigation programs provides funding for the measures described above, encourage flood-preparedness and breaking the traditional cycle of emergency planning-response-recovery.

Measures that improve emergency planning, evacuation, and post-flood recovery reduce the risk to life and property through improvements in emergency planning and risk evaluation. These measures include improving flood forecasting and warning; improving emergency planning and evacuation procedures; improving requirements for post-flood recovery assistance, assuring that damages are not repeated in the future; and streamlining the permitting process for levee repair following flood events.

Measures that increase public awareness and understanding of flood risk could affect decisions regarding current and future development in floodplains. This family of measures includes improving and promoting flood education and awareness programs; improving the communication of flood risk (revising flood risk terminology, communicating residual risk, etc.); accelerating and improving floodplain mapping; modifying Federal insurance requirements; and increasing participating in the Community Rating System program (recognizing and encouraging communities that engage in floodplain management activities).

Measures that integrate flood planning in land use decisions would direct future development outside the floodplain and advocate appropriate use of flood-prone lands. These measures include revising general plans to achieve no-net-loss of floodplain storage and no-net-increase in runoff from new development; establishing user fees for developments with increased flood risk and operation and maintenance costs; and implementation of alternative stormwater management techniques (multi-objective methods of reducing runoff from storm events).

### *Summary of Floodplain Management Measures Identified*

Table V-2 summarizes the general evaluation of floodplain management measures in the Lower San Joaquin study area, utilizing the Comprehensive Study screening criteria previously discussed. As noted in the table, all of the floodplain management measures have been retained for further consideration in the study.

**TABLE V-2**
**EVALUATION OF FLOODPLAIN MANAGEMENT MEASURES**

| Measure | General Criteria | | | | | | | Flood Damage Reduction Criteria | | | | | Ecosystem Restoration Criteria | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cost Effectiveness | Acceptability | Ability to Combine with Other Measures | Ability to Integrate with Other Programs | Existing Water Uses | Cultural/ Social Resources | Geographic Extent of Benefits | Effect on Peak Flow | Effect on Peak Stage | Effect on "High" Flow Duration | System Reliability | FDR Effectiveness | Habitat Quantity/ Quality | Self-Sustaining Geomorphological Processes | Ecological Diversity | Preservation of Agriculture and its Ecological Value |
| **Measure that Modify Susceptibility to Flood Damage** | | | | | | | | | | | | | | | | |
| Flood Proof Structures | med | med | med | med | med | med | med | high | high | med | high | high | med | very high | med | med |
| Relocate Structures | med | med | med | med | med | med | med | high | high | med | high | high | med | very high | med | med |
| Secure Flowage Easements | high | med | med | med | med | med | med | high | high | med | high | high | high | very high | high | high |
| Increase Funding for Pre-Flood Hazard Mitigation | med | high | very high | med | med | high | med | med | med | med | high | med | med | med | med | med |
| **Measures that Improve Emergency Planning, Evacuation and Post Flood Recovery** | | | | | | | | | | | | | | | | |
| Improve Flood Forecasting and Warning | high | very high | very high | med | med | very high | very high | high | high | med | med | high | med | med | med | med |
| Improve Emergency Planning and Evacuation | high | very high | very high | med | med | very high | very high | med | med | med | med | high | med | med | med | med |
| Improve Requirements for Post-Flood Recovery Assistance | high | very high | very high | med | med | very high | very high | med | med | med | med | med | med | med | med | med |
| Streamline the Permitting Process for Levee Repair Following Flood Events | high | med | high | low | med | med | med | med | med | med | high | med | med | med | med | med |

**TABLE V-2 (CONT.)**

| Measure | General Criteria | | | | | | | Flood Damage Reduction Criteria | | | | | Ecosystem Restoration Criteria | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cost Effectiveness | Acceptability | Ability to Combine with Other Measures | Ability to Integrate with Other Programs | Existing Water Uses | Cultural/ Social Resources | Geographic Extent of Benefits | Effect on Peak Flow | Effect on Peak Stage | Effect on "High" Flow Duration | System Reliability | FDR Effectiveness | Habitat Quantity/ Quality | Self-Sustaining Geomorphological Processes | Ecological Diversity | Preservation of Agriculture and its Ecological Value |
| **Measures that Increase Awareness and Understanding of Flood Risk** | | | | | | | | | | | | | | | | |
| Improve and Promote Flood Education and Awareness Programs | high | very high | very high | low | med | very high | very high | med | med | med | med | med | med | med | med | med |
| Improve the Communication of Flood Risk | high | very high | very high | low | med | very high | very high | med | med | med | med | med | med | med | med | med |
| Accelerate and Improve Floodplain Mapping | med | very high | very high | low | med | high | very high | med | med | med | med | med | med | med | med | med |
| Modify Federal Insurance Requirements | med | med | very high | low | med | med | very high | med | med | med | med | med | med | med | med | med |
| Increase Participation in the Community Rating System | med | very high | very high | low | med | high | very high | med | med | med | med | high | med | med | med | med |
| **Measures that Integrate Flood Planning in Land Use Decisions** | | | | | | | | | | | | | | | | |
| Revise General Plan to Achieve No-Net Loss of Floodplain Storage and No-Net-Increase in Runoff from Development | med | med | very high | low | med | med | very high | med | med | med | med | med | med | med | med | med |
| Establish User Fee for Increased Flood Risk | med | med | very high | low | med | med | very high | med | med | med | med | med | med | med | med | med |
| Implement Alternative Storm Water Management Techniques | med | med | very high | low | med | med | very high | med | med | med | med | med | med | med | med | med |

Key:

- (shaded) Measure retained for further consideration
- (unshaded) Measure not retained for further consideration

**Summary of Measures Retained for Consideration**

Table V-3 summarizes the preliminary measure screening results in the Lower San Joaquin study area, indicating which measures have been retained for further consideration.

**TABLE V-3**
**MEASURE SCREENING RESULTS IN THE LOWER SAN JOAQUIN STUDY AREA**

| Measure | | Description | Evaluation |
|---|---|---|---|
| **STORAGE MEASURES** | | | |
| *Modify Objective Releases* | No existing flood control reservoirs in study area | Not Applicable | |
| *Modify Objective Release Schedule* | Not Applicable | Not Applicable | |
| *Conjunctive Use* | No opportunities identified | Not Applicable | |
| *Off-Stream Storage* | No opportunities identified | Not Applicable | |
| *Raise Dam* | Not Applicable | Not Applicable | |
| *Surcharge Spillways* | Not Applicable | Not Applicable | |
| *New On-Stream Storage* | Not Applicable | Not Applicable | |
| *Re-Operate Existing Transient Storage;* | No opportunities identified | Not Applicable | |
| *Enlarge Existing Transient Storage* | No opportunities identified | Not Applicable | |
| *New Transient Storage* | No opportunities identified | Not Applicable | |
| **CONVEYANCE MEASURES** | | | |
| *Modify Existing Conveyance* | Clearing and Snagging (vegetation removal) | Middle River, Old River, Paradise Cut; Not applicable on San Joaquin River (vegetation not a significant factor) | Not Retained – Little effect on flooding and conflicts with ecosystem restoration efforts of this and other programs. |
| | Dredging/Sediment Removal | San Joaquin River and distributaries | Retained |
| | Reduce Constrictions and Hard Points | Rock protection removal on San Joaquin River | Retained |
| | Weir Modification | Paradise Cut Weir | Retained |
| | Strengthen Levees | San Joaquin River and distributaries | Retained – as necessary |
| | Channelization | No opportunities identified | Not Applicable |
| *Enlarge Conveyance* | Raise Existing Levees | San Joaquin River and distributaries | Retained – as necessary |
| | Realign Existing Levees | San Joaquin River and distributaries to increase capacity or remove constrictions | Retained – San Joaquin River, Paradise Cut |
| | Construct New Levees | San Joaquin River and distributaries; back-up levees | Retained – back-up levees |
| | Construct New Bypass | No opportunities identified | Not Applicable |
| *Habitat Restoration* | Restore Riparian, Wetland and Upland Habitat | San Joaquin River and distributaries | Retained – supports ecosystem restoration efforts of this and other programs |

**TABLE V-3 (CONT.)**

| Measure | | Description | Evaluation |
|---|---|---|---|
| **FLOODPLAIN MANAGEMENT MEASURES** | | | |
| *Measure that Modify Susceptibility to Flood Damage* | Flood Proof Structures | Non-urban areas located in the floodplain of the San Joaquin River and its tributaries | Retained |
| | Relocate Structures | Non-urban areas located in the floodplain of the San Joaquin River and its tributaries | Retained |
| | Secure Flowage Easements | Non-urban areas located in the floodplain of the San Joaquin River and its tributaries | Retained |
| | Increase Funding for Pre-Flood Hazard Mitigation | Floodplain of the San Joaquin River and its tributaries | Retained |
| *Measures that Improve Emergency Planning, Evacuation and Post Flood Recovery* | Improve Flood Forecasting and Warning | San Joaquin River Basin | Retained |
| | Improve Emergency Planning and Evacuation | Floodplain of the San Joaquin River and its tributaries | Retained |
| | Improve Requirements for Post-Flood Recovery Assistance | San Joaquin River Basin | Retained |
| | Streamline the Permitting Process for Levee Repair Following Flood Events | Floodplain of the San Joaquin River and its tributaries | Retained |
| *Measures that Increase Awareness and Understanding of Flood Risk* | Improve and Promote Flood Education and Awareness Programs | San Joaquin River Basin | Retained |
| | Improve the Communication of Flood Risk | San Joaquin River Basin | Retained |
| | Accelerate and Improve Floodplain Mapping | Floodplain of the San Joaquin River and its tributaries | Retained |
| | Modify Federal Insurance Requirements | Floodplain of the San Joaquin River and its tributaries | Retained |
| | Increase Participation in the Community Rating System | San Joaquin River Basin | Retained |
| *Measures that Integrate Flood Planning in Land Use Decisions* | Revise General Plan to Achieve No-Net Loss of Floodplain Storage and No-Net-Increase in Runoff from Development | San Joaquin River Basin | Retained |
| | Establish User Fee for Increased Flood Risk | San Joaquin River Basin | Retained |
| | Implement Alternative Storm Water Management Techniques | San Joaquin River Basin | Retained |

The results presented in this table represent the preliminary measure screening findings. The screening analysis does not ensure that these measures will be included in the Final Master Plan developed by the Comprehensive Study. The measures retained will be reserved for further evaluation and planning efforts and combined with other measures to develop master plan concepts and alternatives. Of those retained on this preliminary list, several require additional study or analysis to further define their effectiveness and applicability in this hydraulically complex study area. The hydraulic models developed for use in this area were used to evaluate these measures, which include dredging/sediment removal, constriction removal, weir modification, realigning levees, and back-up levees.

## FLOOD MANAGEMENT SCENARIOS

This study focuses on evaluating measures in the Lower San Joaquin study area and identifying those that meet or contribute to the goals and objectives of the Comprehensive Study. As stated previously, the Comprehensive Study is focused on identifying measures that contribute to system-wide flood damage reduction and related ecosystem restoration values. Hydraulic models can be used to evaluate measures and determine whether their benefits are localized or contribute to the San Joaquin system as a whole. In general, measures that only provide local benefits will not be carried forth in planning efforts. The hydraulic models can also be used to evaluate potential downstream hydraulic impacts to the Delta.

This section discusses the development of several scenarios designed to evaluate the hydraulic performance of several of the retained conveyance measures: dredging/sediment removal, constriction removal, weir modification, realigning levees, and back-up levees. Although other measures have been retained in this study area, the hydraulic nature of these measures warrants additional evaluation to determine their effectiveness in this complex, distributary system.

### Scenario Development

Three scenarios have been developed to evaluate a range of potential conveyance measures in the Lower San Joaquin study area. The first scenario was used to evaluate the benefits of dredging/sediment removal on a distributary channel. The second scenario evaluated the removal of a constriction, representing a moderate system modification. The third scenario evaluated a levee realignment project along the San Joaquin and Old Rivers, representing a major structural modification to the existing flood control system. The three scenarios are described below.

**Scenario 1 – Dredging/Sediment Removal in Middle River:** Under this scenario, the upstream portion of Middle River would be dredged to remove sediment and increase the flood carrying capacity of the river. Several levels of dredging/sediment removal were evaluated, representing a range of dredging alternatives This scenario would represent a minor modification to the existing flood control system in the Lower San Joaquin study area.

**Scenario 2 - Constriction Removal on Paradise Cut:** A segment of Paradise Cut, roughly between RM 6.7 and 6.0, has been identified as a flow constriction. This scenario would involve realigning the left bank levee between 300 and 400 feet back from its current alignment to create a cross sectional flow area roughly equivalent to that upstream and downstream from this reach. It would also involve removal/reconstruction of three bridges in the reach, and modification to the Paradise Cut Weir to divert more flood flow from the San Joaquin River. This scenario would be considered a moderate structural modification to the existing flood control system.

**Scenario 3 – Major Levee Realignment on San Joaquin River and Old River:** This scenario would involve levee realignments along the San Joaquin River downstream from Vernalis to Old River, on Old River from the San Joaquin to Middle River, and along the upper Middle River. It represents a major structural modification to the existing flood control system in the Lower San Joaquin study area. This scenario would involve either degrading the old levees adjacent to the river, or ceasing maintenance and allowing them to degrade over time. This scenario would also include removing the constriction on Paradise Cut (as in Scenario 2), and dredging/sediment removal on Middle River (as in Scenario 1). The scenario is designed to force more flow down Paradise Cut and Old River, diverting the flood wave from major urban areas near Stockton.

**Scenario Evaluation**

Scenarios were evaluated using both the SJRUNET and DSM2 models. Simulations were performed first in SJRUNET, then results were passed to DSM2 to simulate impacts to regions of the Delta not covered by the SJRUNET model. For more information on the content and limitations of the UNET and DSM2 models, please refer to previous chapters of this document, *Appendix D – Hydraulic Technical Documentation, F4 In-Progress Review*, (COE, October 2001) and *Existing Hydrodynamic Conditions in the Delta During Floods,* (COE, 2001).

The scenarios were modeled under 10-, 50-, 100-, 200-, and 500-year storm events. The scenarios were also evaluated both with- and without levee strengthening. The levee strengthening component was modeled by assuming that the levees would fail by overtopping only (likely failure point at the top of the existing levee). This was simulated in SJRUNET by changing the levee failure elevation “trigger” in the baseline model to the top of levee elevation. Levee failure simulation is not supported in DSM2, and was therefore not modeled outside the Comprehensive Study project area.

Hydrologic input to the SJRUNET model was from baseline and infinite channel simulations performed previously by the Comprehensive Study. The baseline SJRUNET runs assume existing conditions throughout the Comprehensive Study area and allow levee breaches to occur as estimated by geotechnical evaluations. The infinite channel SJRUNET runs assume that all flow is contained within the channels of the flood control system. Infinite channel runs are modeled without levee breaches and assume a ‘vertical wall’ when water surfaces exceed top of levee elevations. Because no levee breaches or overtopping occurs, the infinite channel runs result in much greater flows in the system and into the Delta. Infinite channel data was utilized upstream from the Vernalis gage in one set of scenario runs to simulate a “worst case” scenario regarding the potential magnitude of flows entering the Lower San Joaquin study area. For all scenario simulations, baseline data was used downstream from Vernalis.

Table V-4 summarizes the various SJRUNET model simulations performed and assumptions made, including input data and levee assumptions.

The outflows at SJRUNET’s downstream boundary nodes were used as inflows to DSM2 simulation. All other boundary conditions of DSM2 simulations are held constant, and the major assumptions are presented in Chapter III. Baseline hydrologic conditions were used for the Sacramento River and eastside streams. The tidal ranges at Martinez is the modified 1997 tides. Details of the baseline hydrologies of Delta tributaries and the modified 1997 tides at Martinez are presented in *Existing Hydrodynamic Conditions in the Delta during Floods* (COE, 2001).

**TABLE V-4**
**SCENARIOS MODELED IN UNET**

| Scenario No. | Hydrologic Input to SJRUNET[1] | | Levee Failure[2] | *Measures / Components* | | | | |
|---|---|---|---|---|---|---|---|---|
| | U/S Vernalis | D/S Vernalis | | Middle River Dredging | Paradise Cut Constrict. Removal | San Joaquin Levee Realign | Old River Levee Realign | Middle River Levee Realign |
| ***Baseline – Existing Conditions*** | | | | | | | | |
| 0-1 | Baseline | Baseline | LFP | | | | | |
| 0-2 | Baseline | Baseline | TOL | | | | | |
| 0-3 | Inf Chan | Baseline | LFP | | | | | |
| 0-4 | Inf Chan | Baseline | TOL | | | | | |
| ***Scenario 1 – Dredging/Sediment Removal*** | | | | | | | | |
| 1-1 | Baseline | Baseline | LFP | X | | | | |
| 1-2 | Baseline | Baseline | TOL | X | | | | |
| 1-3 | Inf Chan | Baseline | LFP | X | | | | |
| 1-4 | Inf Chan | Baseline | TOL | X | | | | |
| ***Scenario 2 – Constriction Removal*** | | | | | | | | |
| 2-1 | Baseline | Baseline | LFP | | X | | | |
| 2-2 | Baseline | Baseline | TOL | | X | | | |
| 2-3 | Inf Chan | Baseline | LFP | | X | | | |
| 2-4 | Inf Chan | Baseline | TOL | | X | | | |
| ***Scenario 3 – Major Structural Modification*** | | | | | | | | |
| 3-1 | Baseline | Baseline | LFP | X | X | X | X | X |
| 3-2 | Baseline | Baseline | TOL | X | X | X | X | X |
| 3-3 | Inf Chan | Baseline | LFP | X | X | X | X | X |
| 3-4 | Inf Chan | Baseline | TOL | X | X | X | X | X |

*Notes:*
1. *Model input was either from SJRUNET baseline (existing conditions) or infinite channel (Inf Chan) simulations.*
2. *Two levee failure modes were modeled: (1) LFP (likely failure point) signifying existing levee strength conditions, and (2) TOL (top of levee) signifying strengthened levees that fail by overtopping only.*

## Scenario 1 – Dredging/Sediment Removal

### *General Description*

Under this scenario, the upstream portion of Middle River would be dredged to remove sediment and increase the flood carrying capacity of the channel. The depth of dredging would vary between 20 feet and 80 feet, depending on the shape of the cross section. Three levels of dredging/sediment removal were evaluated under this scenario, as described below:

**Scenario 1a** – Dredging/sediment removal between RM 28.3 (upstream end of Middle River) and RM 27.0 (upstream from Undine Road Bridge). The total length of dredged channel would be about 1.3 miles.

**Scenario 1b** – Dredging/sediment removal between RM 28.3 and 27.0 (same as Scenario 1a), and removal of the Undine Road Bridge. The total length of dredged channel would be about 1.3 miles.

**Scenario 1c** – Dredging/sediment removal between RM 28.3 and 20.3. The total length of dredged channel would be about 8 miles.

### *Hydraulic Modeling and Assumptions*

The three dredging/sediment removal scenarios were initially modeled in SJRUNET for a 100-year flood event. As shown in Table V-5, Scenarios 1b and 1c did not significantly increase the flow capacity of the reach over that of Scenario 1a. This indicates that removal of the Undine Road Bridge and extension of the dredging farther downstream has no incremental benefit. Consequently, only Scenario 1a will be referenced in the later discussion for reporting results on dredging/sediment removal (scenario 1).

**TABLE V-5**
**COMPARISON OF DREDGING/SEDIMENT REMOVAL SCENARIOS**
**IN THE MIDDLE RIVER**

| Scenario | Baseline | Scenario 1a | Scenario 1b | Scenario 1c |
|---|---|---|---|---|
| Peak Flow (cfs) | 3,629 | 5,358 | 5,376 | 5,488 |
| Increase from Baseline | - | 47% | 48% | 51% |

*Notes: Values above represent SJRUNET simulation results for a 100-year flood event.*

Scenario 1a was then modeled in both SJRUNET and DSM2 for each of the five storm events and the two levee failure scenarios. Changes were made to the existing SJRUNET cross section geometry. The stability of the channel banks was not taken into consideration for the purpose of this analysis. Some form of bank stabilization may be required in conjunction with the dredging/sediment removal. Sediment removal was carried out at cross sections that presented smaller flow areas. The levee strengthening component was modeled by assuming that the levees would fail by overtopping only (likely failure point at the top of the existing levee). This was simulated in SJRUNET by changing the levee failure elevation "trigger" in the baseline model to the top of levee elevation.

### *Major Accomplishments*

The major accomplishment of this scenario is increased conveyance capacity in Middle River. This scenario would increase the flow capacity of Middle River by just under 50%, representing about a 1,750 cfs increase in flow during a 100-year event. This increase is relatively small compared with the 100-year flow of about 75,000 cfs that enters the study area from the San Joaquin River near Vernalis. Note that the peak out flows from Middle River have not changed due to downstream control. No significant change in flow peaks have occurred in other waterways. In addition, no significant change in stage, either in Middle River or adjacent waterways, was indicated by the model simulations. Table V-6 compares the simulated peak flows for Scenario 1 with baseline conditions for the five storm events simulated in SJRUNET. Table V-7 compares simulated peak flows in the DSM2 model area. DSM2 model results indicate little affects to the Delta downstream of the Comprehensive Study project area.

# TABLE V-6
# COMPARISON OF SIMULATED PEAK FLOWS FOR BASELINE AND SCENARIO 1 - SJRUNET

| SJRUNET Index Location | Return Period (yrs) | Without Levee Strengthening | | With Levee Strengthening | |
|---|---|---|---|---|---|
| | | *Baseline* | *Scenario 1* | *Baseline* | *Scenario 1* |
| *San Joaquin River at Vernalis* | 10 | 33,196 | 33,196 | 32,950 | 32,950 |
| | 50 | 43,040 | 43,040 | 44,916 | 44,917 |
| | 100 | 68,990 | 68,989 | 71,257 | 71,261 |
| | 200 | 105,147 | 105,147 | 107,840 | 107,854 |
| | 500 | 151,167 | 151,168 | 151,313 | 151,547 |
| *San Joaquin River Downstream from Old River* | 10 | 25,269 | 25,260 | 25,051 | 25,064 |
| | 50 | 31,655 | 31,650 | 32,819 | 32,834 |
| | 100 | 38,897 | 38,856 | 45,715 | 45,741 |
| | 200 | 47,898 | 47,936 | 60,709 | 61,117 |
| | 500 | 52,723 | 52,665 | 79,130 | 79,403 |
| *Old River D/S from Middle River* | 10 | 15,291 | 15,460 | 18,937 | 18,987 |
| | 50 | 16,212 | 16,313 | 24,754 | 24,805 |
| | 100 | 16,546 | 17,057 | 33,963 | 34,041 |
| | 200 | 17,040 | 17,730 | 40,483 | 43,658 |
| | 500 | 24,656 | 26,091 | 45,258 | 49,663 |
| *Middle River near Old River* | 10 | 1,669 | 1,945 | 2,080 | 2,377 |
| | 50 | 2,433 | 3,000 | 2,956 | 3,328 |
| | 100 | 3,629 | 5,358 | 4,355 | 4,811 |
| | 200 | 4,323 | 6,038 | 5,461 | 17,712 |
| | 500 | 7,598 | 13,115 | 7,256 | 20,033 |
| *Middle River - SJRUNET Downstream boundary* | 10 | 972 | 972 | 2,080 | 2,233 |
| | 50 | 4,306 | 4,697 | 2,498 | 2,667 |
| | 100 | 10,206 | 10,612 | 3,132 | 3,338 |
| | 200 | 15,246 | 15,488 | 3,549 | 8,291 |
| | 500 | 20,775 | 21,198 | 12,574 | 13,932 |

*Notes:* 1. *Peak flow and peak stage may not occur at the same time.*
2. *The simulation without levee strengthening assumes that all flow is contained in the channel*

**TABLE V-7**
**COMPARISON OF SIMULATED PEAK FLOWS**
**FOR BASELINE AND SCENARIO 1 – DSM2**

| DSM2 Index Location | Return Period (yrs) | Without Levee Strengthening | | With Levee Strengthening | |
|---|---|---|---|---|---|
| | | *Baseline* | *Scenario 1* | *Baseline* | *Scenario 1* |
| *Victoria Canal* | 10 | 8,680 | 8,726 | 9,461 | 9,307 |
| | 50 | 11,192 | 11,062 | 12,662 | 12,470 |
| | 100 | 13,583 | 13,474 | 17,951 | 17,722 |
| | 200 | 16,290 | 15,976 | 22,037 | 19,440 |
| | 500 | 19,994 | 19,344 | 29,540 | 26,896 |
| *San Joaquin River @ Venice Island* | 10 | 4,734 | 4,744 | 4,520 | 4,519 |
| | 50 | 7,750 | 7,711 | 7,254 | 7,253 |
| | 100 | 8,270 | 8,274 | 7,567 | 7,567 |
| | 200 | 8,523 | 8,529 | 7,979 | 7,984 |
| | 500 | 9,711 | 9,713 | 9,366 | 9,369 |
| *Middle River @ UVM* | 10 | 8,332 | 8,382 | 9,578 | 9,563 |
| | 50 | 10,573 | 10,587 | 10,949 | 10,920 |
| | 100 | 13,013 | 13,040 | 13,789 | 13,754 |
| | 200 | 15,703 | 15,721 | 15,874 | 15,579 |
| | 500 | 21,884 | 21,908 | 20,552 | 21,157 |
| *Old River @UVM* | 10 | 16,253 | 16,326 | 18,145 | 18,108 |
| | 50 | 19,586 | 19,582 | 20,034 | 19,977 |
| | 100 | 23,287 | 23,321 | 24,613 | 24,547 |
| | 200 | 27,406 | 27,433 | 27,882 | 27,356 |
| | 500 | 37,403 | 37,438 | 35,330 | 36,249 |
| *Jersey Point* | 10 | 208,316 | 208,417 | 207,347 | 207,411 |
| | 50 | 222,071 | 222,071 | 226,154 | 226,148 |
| | 100 | 232,081 | 232,091 | 240,691 | 240,576 |
| | 200 | 243,658 | 243,614 | 252,589 | 250,528 |
| | 500 | 262,858 | 262,851 | 288,563 | 285,257 |

*Notes: 1. Peak flow and peak stage may not occur at the same time.*
*2. DSM2 assumes that all flow remains in the channel. The levee conditions refer to the SJRUNET model, which provides input to DSM2.*

### *Impacts*

DSM2 model results indicate that this measure would have no significant hydraulic impacts to the Delta downstream from the Comprehensive Study project area.

This scenario would have negative environmental impacts. Potential threatened and endangered species that may be present in the area include the giant garter snake, delta smelt, and splittail. This scenario would involve the removal of channel sediments using mechanical equipment (bulldozers, draglines, and front-end loaders). Sediment removal would disturb aquatic and benthic (river bottom) habitat and would temporarily effect water quality. Impacts to water quality could be minimized by constructing temporary flow barriers and conducting the dredging during low-flow/low-tide periods (summer months).

Dredging/sediment removal may also disturb vegetation and habitat adjacent to the channel. Measures could be taken to minimize or limit the disturbance of habitat and vegetation along channel banks, such as requiring that work be conducted only from one side of the channel or requiring that work be conducted from barges (using draglines or traditional dredging equipment). The work would have to be scheduled to minimize impacts to any threatened and endangered species inhabiting the area.

Although the initial construction impacts to the environment would be negative, it is possible that this scenario could provide some benefit to aquatic species in the area by increasing the depth of water in the channel. Increased channel depth may result in lower water temperatures or allow aquatic species to inhabit this channel longer or during low-flow periods. These potential incidental benefits can not be quantified at this time.

#### *Costs*

The initial capital cost of Scenario 1 would be low compared with Scenarios 2 and 3. Some sediment removed from the channel may have commercial value and could be either given or sold to private interests for their use. The commercial value would depend on the demand for fill at the time of dredging/sediment removal and can not be estimated at this time.

Sediment may continue to be deposited in this reach after the scenario was implemented. For this reason, this scenario would require periodic reapplication to maintain channel capacity. The period of time between re-dredging would depend on several factors, including flow regime and the occurrence of large flood events, and can not be determined at this time. No other operation/maintenance costs would be required.

#### *Implementation Conditions*

Implementation of this scenario would require numerous permits and consultations with Federal, State, and local regulatory agencies. Negative environmental impacts may require mitigation. Were this scenario to be implemented by the Comprehensive Study its impacts would be addressed under the programmatic EIR/EIS being developed. The following lists the major consultations that may be required for implementation of dredging/sediment removal on Middle River, listed by the granting agency:

- U.S. Fish and Wildlife Service (USFWS) - The USFWS is responsible for consulting on the effects of federal projects on threatened and endangered species pursuant to Section 7 of the federal Endangered Species Act (ESA).
- National Marine Fisheries Service (NMFS) – The NMFS is responsible for consulting on the effects of federal projects on threatened and endangered anadromous fish species (Biological Opinion) pursuant to Section 7 of the ESA.
- U.S. Army Corps of Engineers – This scenario may require a Section 404 permit from the Corps for activities that place or disturb fill material in the water. A Section 10 permit may be required if construction requires the placement of temporary flow barriers or other structures within the channel.

- California Department of Fish and Game (DFG) – The DFG is charged with protecting state-listed species in accordance with the California Endangered Species Act (CESA). A Streambed Alteration Agreement may also be required under Chapter 6 and Section 1600 et seq. of the California Fish and Game Code.
- Regional Water Quality Control Board (RWQCB) – Certification that the project would not substantially impact water quality conditions is required pursuant to Section 401 of the Clean Water Act. A dewatering permit may also be required.
- Reclamation Board of the State of California – The Reclamation Board has permit authority over most projects that affect major levees. An Encroachment Permit may be required.
- Other Local Permissions – Permission may be required from the County or other local agencies or landowners for issues such as construction access, noise, and water quality, as necessary.

**Scenario 2 – Constriction Removal**

***General Description***

Paradise Cut diverts flow from the San Joaquin River near RM 58.56. Flood flows travel northwest through the cut before joining Old River. Paradise Cut forms the southwestern boundary of Stewart Track, an island that is bound on the east by the San Joaquin River and on the north by Old River. A major highway, Interstate 5, and a major rail line, the Union Pacific Railroad, cross Paradise Cut near its upstream end. Stewart Tract has been subjected to flooding numerous times over the last century, most recently in 1997 as a result of levee overtopping and piping along Paradise Cut.

A segment of Paradise Cut, roughly between RM 6.7 and 6.0, has been identified as a flow constriction. Flow through Paradise Cut is constricted by three bridges (I-5, HWY 205, and the UPRR) and a geometric constriction (channel narrowing) in this section. The average channel width (distance from left levee crown to right levee crown) in this section decreases from about 900 feet just upstream and downstream, to about 500 feet at the constriction. Backwater caused by this constriction has resulted in higher flood stage and levees in the area immediately upstream have experienced failures. This scenario would involve realigning the left bank levee between 300 and 400 feet back from its current alignment to create a cross sectional flow area roughly equivalent to that upstream and downstream from this reach. It would also involve removal/reconstruction of three bridges in the reach, and modification to the Paradise Cut Weir to divert more flood flow from the San Joaquin River.

Constriction removal, levee realignment, and backup levees have similar hydraulic characteristics: increased conveyance capacity through widening the available flow area. In addition, constriction removal often involves some form of levee realignment or backup levee construction. Therefore, this scenario may be considered representative of similar measures to increase channel flow capacity in San Joaquin River distributary channels (Middle River, Old River, etc.) such as levee realignment and back-up levees. It also incorporates the Paradise Cut Weir modification measure that was retained from the measure screening process.

### *Hydraulic Modeling and Assumptions*

Changes were made to the existing SJRUNET geometry to reflect the levee realignment and weir modification. For the purpose of modeling, the three bridges (I-5, Hwy 205, and the UPRR) were removed to ensure that flow in the channel is unrestricted, representing a best-case condition. If this measure were to be implemented, these bridges would likely be reconstructed with hydraulically superior cross sections. Manning's roughness coefficient (channel "*n*" value) for the expanded left overbank was changed to match the roughness of the channel overbank immediately upstream. The right bank levee was left unchanged.

The hydraulic modeling effort also examined the effectiveness of widening the Paradise Cut Weir. Model iterations were performed in which the weir was lowered and/or widened to allow more flow to be diverted into Paradise Cut. However, the depth of water over the top of the weir (submergence) during flood events is high enough that these changes had little effect on the amount of flow entering Paradise Cut. Consequently, it was determined that modifying the Paradise Cut Weir was not an effective measure by itself under current flood flow conditions in the San Joaquin River. However, if flood stage in the San Joaquin were to be significantly reduced by other measures under consideration by the Comprehensive Study, modification to the weir could be required to ensure that it continues to operate as intended.

### *Major Accomplishments*

Removal of the constriction along upper Paradise Cut would result in an increase in the flow capacity of the cut and a reduction in the stage immediately upstream of the flow constriction. However, the peak flows in the waterway including Paradise Cut, would not change much. This is because most waterways in the Lower San Joaquin River would act like a pool due to downstream stage conditions. The insignificant changes in outflows from the SJRUNET modeling area would result in insignificant changes in flow and stage in the remaining Delta modeled by DSM2.Modeling results for the SJRUNET model area are summarized in Table V-8, and for the DSM2 model area in Table V-9.

**TABLE V-8**
**COMPARISON OF SIMULATED PEAK FLOWS**
**FOR BASELINE AND SCENARIO 2 – SJRUNET**

| **SJRUNET Index Location** | Return Period (yrs) | **Without Levee Strengthening** | | **With Levee Strengthening** | |
|---|---|---|---|---|---|
| | | *Baseline* | *Scenario 2* | *Baseline* | *Scenario 2* |
| *San Joaquin River at Vernalis* | 10 | 33,196 | 33,202 | 32,950 | 32,952 |
| | 50 | 43,040 | 43,035 | 44,916 | 44,948 |
| | 100 | 68,990 | 68,991 | 71,257 | 71,294 |
| | 200 | 105,147 | 105,170 | 107,840 | 107,884 |
| | 500 | 151,167 | 151,231 | 151,313 | 151,784 |
| *San Joaquin River Downstream from Old River* | 10 | 25,269 | 24,825 | 25,051 | 24,447 |
| | 50 | 31,655 | 31,221 | 32,819 | 31,754 |
| | 100 | 38,897 | 38,160 | 45,715 | 44,261 |
| | 200 | 47,898 | 47,761 | 60,709 | 58,542 |
| | 500 | 52,723 | 51,691 | 79,130 | 77,854 |
| *Old River D/S from Middle River* | 10 | 15,291 | 15,290 | 18,937 | 18,445 |
| | 50 | 16,212 | 15,880 | 24,754 | 23,891 |
| | 100 | 16,546 | 16,242 | 33,963 | 32,848 |
| | 200 | 17,040 | 16,601 | 40,483 | 39,321 |
| | 500 | 24,656 | 23,966 | 45,258 | 44,051 |
| *Middle River near Old River* | 10 | 1,669 | 1,663 | 2,080 | 2,065 |
| | 50 | 2,433 | 2,445 | 2,956 | 2,929 |
| | 100 | 3,629 | 3,636 | 4,355 | 4,358 |
| | 200 | 4,323 | 4,336 | 5,461 | 5,539 |
| | 500 | 7,598 | 7,823 | 7,256 | 7,388 |
| *Middle River – SJRUNET Downstream boundaryl* | 10 | 1,195 | 1,195 | 2,080 | 2,065 |
| | 50 | 4,306 | 4,262 | 2,498 | 2,485 |
| | 100 | 10,206 | 10,138 | 3,132 | 3,133 |
| | 200 | 15,246 | 15,150 | 3,549 | 3,840 |
| | 500 | 20,775 | 20,676 | 12,574 | 12,117 |

*Notes: 1. Peak flow and peak stage may not occur at the same time.*
*2. The simulation without levee strengthening assumes that all flow is contained in the channel.*

**TABLE V-9**
**COMPARISON OF SIMULATED PEAK FLOWS**
**FOR BASELINE AND SCENARIO 2 – DSM2**

| **DSM2 Index Location** | Return Period (yrs) | **Without Levee Strengthening** | | **With Levee Strengthening** | |
|---|---|---|---|---|---|
| | | *Baseline* | *Scenario 2* | *Baseline* | *Scenario 2* |
| *Victoria Canal* | 10 | 8,680 | 8,761 | 9,461 | 9,511 |
| | 50 | 11,192 | 10,867 | 12,662 | 12,773 |
| | 100 | 13,583 | 13,623 | 17,951 | 18,352 |
| | 200 | 16,290 | 16,413 | 22,037 | 23,176 |
| | 500 | 19,994 | 20,382 | 29,540 | 29,681 |
| *San Joaquin River @ Venice Island* | 10 | 4,734 | 4,734 | 4,520 | 4,520 |
| | 50 | 7,750 | 7,750 | 7,254 | 7,253 |
| | 100 | 8,270 | 8,270 | 7,567 | 7,566 |
| | 200 | 8,523 | 8,523 | 7,979 | 7,977 |
| | 500 | 9,711 | 9,709 | 9,366 | 9,366 |
| *Middle River @ UVM* | 10 | 8,332 | 8,371 | 9,578 | 9,600 |
| | 50 | 10,573 | 10,551 | 10,949 | 10,996 |
| | 100 | 13,013 | 13,021 | 13,789 | 13,886 |
| | 200 | 15,703 | 15,712 | 15,874 | 16,781 |
| | 500 | 21,884 | 21,932 | 20,552 | 20,632 |
| *Old River @UVM* | 10 | 16,253 | 16,314 | 18,145 | 18,182 |
| | 50 | 19,586 | 19,552 | 20,034 | 20,111 |
| | 100 | 23,287 | 23,302 | 24,613 | 24,769 |
| | 200 | 27,406 | 27,422 | 27,882 | 29,329 |
| | 500 | 37,403 | 37,488 | 35,330 | 35,458 |
| *Jersey Point* | 10 | 208,316 | 208,316 | 207,347 | 207,347 |
| | 50 | 222,071 | 222,073 | 226,154 | 226,156 |
| | 100 | 232,081 | 232,083 | 240,691 | 240,914 |
| | 200 | 243,658 | 243,656 | 252,589 | 253,178 |
| | 500 | 262,858 | 263,246 | 288,563 | 289,280 |

*Notes: 1. Peak flow and peak stage may not occur at the same time.*
*2. DSM2 assumes that all flow remains in the channel. The levee conditions refer to the UNET model, which provides input to DSM2.*

***Impacts***

DSM2 model results indicate that this measure would have no significant hydraulic impacts to the Delta downstream from the Comprehensive Study Project area.

This scenario would have negative environmental impacts. Potential threatened and endangered species that may be present in the area include the giant garter snake, delta smelt, and splittail. This scenario would involve the removal of levee materials using mechanical equipment (bulldozers and front-end loaders). Removal and realignment of the left bank levee would disturb terrestrial habitat, and measures would have to be taken to prevent impacts to aquatic species and water quality. The work could be scheduled to minimize impacts to any threatened and endangered species inhabiting the area.

### *Costs*

The initial capital cost of Scenario 2 would be moderate compared with Scenarios 1 and 3. The greatest cost would be associated with replacement of existing bridges, such as the Union Pacific Railroad Bridge. Reconstruction of the approaches to the Interstate 5 bridge may be required and would also present a significant capital cost. Operation and maintenance for this scenario would not change over existing conditions, as this scenario would realign existing levees but would not construct any new features.

### *Implementation Conditions*

Implementation of this scenario would require numerous permits and consultations with Federal, State, and local regulatory agencies. Negative environmental impacts may require mitigation. Were this scenario to be implemented by the Comprehensive Study its impacts would be addressed under the programmatic EIR/EIS being developed. The following lists the major consultations that may be required for implementation of levee realignment and constriction removal on Paradise Cut, listed by the granting agency:

- U.S. Fish and Wildlife Service - The USFWS is responsible for consulting on the effects of federal projects on threatened and endangered species pursuant to Section 7 of the federal Endangered Species Act.
- National Marine Fisheries Service – The NMFS is responsible for consulting on the effects of federal projects on threatened and endangered anadromous fish species (Biological Opinion) pursuant to Section 7 of the ESA. It is anticipated that there would be no impacts to native fisheries with this project.
- U.S. Army Corps of Engineers – This scenario may require a Section 404 permit from the Corps for activities that place or disturb fill material in the water.
- California Department of Fish and Game – The DFG is charged with protecting state-listed species in accordance with the California Endangered Species Act. A Biological Opinion may be required.
- Regional Water Quality Control Board – Certification that the project would not substantially impact water quality conditions is required pursuant to Section 401 of the Clean Water Act.
- Reclamation Board of the State of California – The Reclamation Board has permit authority over most projects that affect major levees. An Encroachment Permit would be required.
- Other Local Permissions – Permission may be required from the County or other local agencies or landowners for issues such as construction access, noise, and water quality, as necessary.

Land would need to be acquired in order to move the existing levees back from the constriction. This would required the support and cooperation of local landowners.

## Scenario 3 – Major Structural Modification

### *General Description*

This scenario would involve levee realignments along the San Joaquin River downstream from Vernalis to Old River, on Old River from the San Joaquin to Middle River, and along the upper end of Middle River. This scenario would also include removing the constriction on Paradise Cut (as described in Scenario 2) and about 1-mile of dredging in Middle River (as described in Scenario 1). It represents a major structural modification to the existing flood control system in the Lower San Joaquin study area. This scenario would involve either degrading the old levees adjacent to the river, or ceasing maintenance and allowing them to degrade over time. The scenario is designed to force more flow down Paradise Cut and Old River, diverting the flood wave from major urban areas near Stockton.

The right bank levee of the San Joaquin River would be realigned between 0 and 1000 feet back from the existing levee alignment, creating a continuous flood corridor. Levees located immediately adjacent to the channel would be set back the full 1000 feet, while sections with levees that area already set back from the river would only be realigned as necessary to maintain corridor width. Along Old River, the right bank levee would be realigned about 1000 feet back from the original levee alignment. Levee realignment along Paradise Cut would be as described for Scenario 2. The levee along Middle River would be realigned about 500 feet back from the river. Dredging along Middle River would be as described in Scenario 1a.

### *Hydraulic Modeling and Assumptions*

Modifications were made to the SJRUNET existing geometry to reflect the levee realignments and constriction removals described above. Model simulations were performed for the five storm events, and the two levee failure assumptions. Modeling assumptions for the Paradise Cut and Middle River elements of this scenario are similar to those described for Scenarios 1 and 2, respectively.

### *Major Accomplishments*

The major flood damage reduction benefits of Scenario 3 would be a reduction in stage along the San Joaquin River and along the upstream portion of Paradise Cut. Flow at Vernalis did not change significantly. That is, the major structural modification would not encourage more flow into the Lower San Joaquin River, indicating an upstream control condition. Little change in stage was observed in Old River. Flow in Middle River and Paradise Cut were somewhat higher with Scenario 3, but other reaches showed no significant increase in flow or stage. DSM2 modeling indicates that there would be no significant impacts to the Delta, downstream from the Comprehensive Study Project area. Table V-10 compares SJRUNET results for Scenario 3 with the baseline condition, and Table V-11 compares DSM2 results.

**TABLE V-10**
**COMPARISON OF SIMULATED PEAK FLOWS**
**FOR BASELINE AND SCENARIO 3 - SJRUNET**

| **SJRUNET Index Location** | Return Period (yrs) | **Without Levee Strengthening** | | **With Levee Strengthening** | |
|---|---|---|---|---|---|
| | | *Baseline* | *Scenario 3* | *Baseline* | *Scenario 3* |
| *San Joaquin River at Vernalis* | 10 | 33,196 | 33,225 | 32,950 | 32,934 |
| | 50 | 43,040 | 43,109 | 44,916 | 45,068 |
| | 100 | 68,990 | 69,272 | 71,257 | 71,517 |
| | 200 | 105,147 | 105,657 | 107,840 | 108,391 |
| | 500 | 151,167 | 152,052 | 151,313 | 152,277 |
| *San Joaquin River Downstream from Old River* | 10 | 25,269 | 24,874 | 25,051 | 24,495 |
| | 50 | 31,655 | 31,328 | 32,819 | 31,937 |
| | 100 | 38,897 | 38,334 | 45,715 | 44,743 |
| | 200 | 47,898 | 47,924 | 60,709 | 58,883 |
| | 500 | 52,723 | 52,003 | 79,130 | 78,338 |
| *Old River D/S from Middle River* | 10 | 15,291 | 15,518 | 18,937 | 18,557 |
| | 50 | 16,212 | 16,098 | 24,754 | 24,136 |
| | 100 | 16,546 | 16,800 | 33,963 | 33,411 |
| | 200 | 17,040 | 17,532 | 40,483 | 40,085 |
| | 500 | 24,656 | 25,914 | 45,258 | 45,333 |
| *Middle River near Old River* | 10 | 1,669 | 2,010 | 2,080 | 2,458 |
| | 50 | 2,433 | 3,025 | 2,956 | 3,491 |
| | 100 | 3,629 | 5,452 | 4,355 | 5,180 |
| | 200 | 4,323 | 6,234 | 5,461 | 6,648 |
| | 500 | 7,598 | 13,434 | 7,256 | 9,318 |
| *Middle River – SJRUNET downstream boundaryl* | 10 | 1,195 | 972 | 2,080 | 2,298 |
| | 50 | 4,306 | 4,753 | 2,498 | 2,776 |
| | 100 | 10,206 | 10,692 | 3,132 | 3,551 |
| | 200 | 15,246 | 15,590 | 3,549 | 4,572 |
| | 500 | 20,775 | 21,391 | 12,574 | 12,792 |

*Notes:* *1. Peak flow and peak stage may not occur at the same time.*
*2. The simulation without levee strengthening assumes that all flow is contained in the channel*

**TABLE V-11**
**COMPARISON OF SIMULATED PEAK FLOWS**
**FOR BASELINE AND SCENARIO 3 – DSM2**

| DSM2 Index Location | Return Period (yrs) | Without Levee Strengthening | | With Levee Strengthening | |
|---|---|---|---|---|---|
| | | *Baseline* | *Scenario 3* | *Baseline* | *Scenario 3* |
| *Victoria Canal* | 10 | 8,680 | 8,660 | 9,461 | 9,296 |
| | 50 | 11,192 | 10,779 | 12,662 | 12,517 |
| | 100 | 13,583 | 13,472 | 17,951 | 18,092 |
| | 200 | 16,290 | 16,111 | 22,037 | 22,876 |
| | 500 | 19,994 | 19,482 | 29,540 | 29,139 |
| *San Joaquin River @ Venice Island* | 10 | 4,734 | 4,744 | 4,520 | 4,519 |
| | 50 | 7,750 | 7,701 | 7,254 | 7,253 |
| | 100 | 8,270 | 8,275 | 7,567 | 7,567 |
| | 200 | 8,523 | 8,528 | 7,979 | 7,982 |
| | 500 | 9,711 | 9,713 | 9,366 | 9,370 |
| *Middle River @ UVM* | 10 | 8,332 | 8,358 | 9,578 | 9,588 |
| | 50 | 10,573 | 10,573 | 10,949 | 10,979 |
| | 100 | 13,013 | 13,068 | 13,789 | 13,841 |
| | 200 | 15,703 | 15,754 | 15,874 | 16,751 |
| | 500 | 21,884 | 22,028 | 20,552 | 20,684 |
| *Old River @ UVM* | 10 | 16,253 | 16,289 | 18,145 | 18,143 |
| | 50 | 19,586 | 19,557 | 20,034 | 20,065 |
| | 100 | 23,287 | 23,363 | 24,613 | 24,678 |
| | 200 | 27,406 | 27,487 | 27,882 | 29,271 |
| | 500 | 37,403 | 37,648 | 35,330 | 35,534 |
| *Jersey Point* | 10 | 208,316 | 208,428 | 207,347 | 207,413 |
| | 50 | 222,071 | 222,094 | 226,154 | 226,148 |
| | 100 | 232,081 | 232,116 | 240,691 | 240,906 |
| | 200 | 243,658 | 243,617 | 252,589 | 253,313 |
| | 500 | 262,858 | 263,276 | 288,563 | 289,390 |

*Notes: 1. Peak flow and peak stage may not occur at the same time.*
*2. DSM2 assumes that all flow remains in the channel. The levee conditions refer to the SJRUNET model, which provides input to DSM2.*

### *Impacts*

DSM2 model results indicate that this measure would have no significant hydraulic impacts to the Delta downstream from the Comprehensive Study Project area.

This scenario would have negative environmental impacts. Potential threatened and endangered species that may be present in the area include the giant garter snake, delta smelt, and splittail. This scenario would involve the removal of levee materials using mechanical equipment (bulldozers and front-end loaders). Removal and realignment of levees would disturb terrestrial habitat, and measures would have to be taken to prevent impacts to aquatic species and water quality. The work could be scheduled to minimize impacts to any threatened and endangered species inhabiting the area.

This scenario would also impact land use in the areas of the levee realignments and may reduce the amount of land in agriculture. These impacts may be reduced if some of the levees were designed as back-up levees, allowing agriculture or other appropriate uses to continue within the floodplain. Back-up levees would reduce the economic impacts associated with acquiring the land for this scenario.

### *Costs*

The initial capital cost of Scenario 3 would be high compared with Scenarios 1 and 2. The greatest costs would be associated with land acquisition and levee realignment along the San Joaquin River and replacement of existing bridges, such as the Union Pacific Railroad Bridge. Reconstruction of the approaches to the Interstate 5 bridge may be required, as noted under Scenario 2. Operation and maintenance for this scenario would not change over existing conditions, as this scenario would realign existing levees but would not construct any new features.

### *Implementation Conditions*

Implementation of this scenario would require numerous permits and consultations with Federal, State, and local regulatory agencies. Negative environmental impacts may require mitigation. Were this scenario to be implemented by the Comprehensive Study its impacts would be addressed under the programmatic EIR/EIS being developed. The following lists the major consultations that may be required for implementation of levee realignment on the San Joaquin and Old Rivers and constriction removal on Paradise Cut, listed by the granting agency:

- U.S. Fish and Wildlife Service - The USFWS is responsible for consulting on the effects of federal projects on threatened and endangered species pursuant to Section 7 of the federal Endangered Species Act.
- National Marine Fisheries Service – The NMFS is responsible for consulting on the effects of federal projects on threatened and endangered anadromous fish species (Biological Opinion) pursuant to Section 7 of the ESA. It is anticipated that there would be no impacts to native fisheries with this project.
- U.S. Army Corps of Engineers – This scenario may require a Section 404 permit from the Corps for activities that place or disturb fill material in the water.
- California Department of Fish and Game – The DFG is charged with protecting state-listed species in accordance with the California Endangered Species Act. A Biological Opinion may be required.
- Regional Water Quality Control Board – Certification that the project would not substantially impact water quality conditions is required pursuant to Section 401 of the Clean Water Act.
- Reclamation Board of the State of California – The Reclamation Board has permit authority over most projects that affect major levees. An Encroachment Permit would be required.

- Other Local Permissions – Permission may be required from the County or other local agencies or landowners for issues such as construction access, noise, and water quality, as necessary.

Land would need to be acquired in order to move the existing levees back from the San Joaquin and Old Rivers. This would require the support and cooperation of local landowners. It is possible that some of the levee realignments could be designed as backup levees, allowing farming and other appropriate practices to continue in the floodplain. This would prevent loss of agricultural lands and the associated economics impacts.

# CHAPTER VI

# SUMMARY AND CONCLUSIONS

## COMPARISON OF MODELING RESULTS

Hydraulic analyses were performed for the three scenarios and two levee failure conditions under 10-, 50-, 100-, 200-, and 500-year flood events. An initial comparison was made between the scenarios to first evaluate the impacts of dredging/sediment removal, constriction removal, and levee realignments. A second comparison was made within each scenario to evaluate the impacts of levee strengthening.

Several index points or control points in the Lower San Joaquin study area were selected to report output and use in comparing the scenario results. These control points are shown in Table VI-1.

**TABLE VI-1**
**CONTROL POINTS IN THE LOWER SAN JOAQUIN STUDY AREA**

| River / Channel | Location |
|---|---|
| San Joaquin River | Downstream from Stanislaus Confluence<br>Vernalis Gage<br>Upstream from Paradise Cut Weir<br>Downstream from Paradise Cut Weir<br>Upstream from Old River bifurcation<br>Downstream end of UNET model (near Stockton) |
| Old River | Downstream from San Joaquin bifurcation<br>Upstream from Middle River bifurcation<br>Downstream from Middle River bifurcation<br>Downstream end of UNET model |
| Middle River | Downstream of Old River bifurcation<br>Downstream end of UNET model |
| Paradise Cut | Upstream End (downstream from weir)<br>Downstream End |
| Grand Line Canal | Downstream end of UNET model |

Tables VI-2 and VI-3 compare the stage and flow results for the three scenarios against the baseline. Profile plots of the simulated water surface in the San Joaquin River, Old River, Middle River, and Paradise Cut are presented in Figures VI-1 through VI-4. The profile plots demonstrate the effect of each scenario on peak river stage for the 100-year flood event, with and without levee strengthening.

**Effects on Flow**

Comparison of simulated flow for the three alternatives with the baseline condition shows that the effects on flow are largely localized to the areas immediately adjacent to the improvement. Results at the downstream ends of the SJRUNET model show little change over baseline conditions, indicating that the effects of the three scenarios do not extend lower into the Delta. Virtually no change in flow was observed at Vernalis for any of the three scenarios. The simulated results indicate that localized effects of the scenarios on flow conditions are re-distributed throughout the distributary channels.

Scenario 3 showed the most significant change in flow, with an increase between 50% and 75% in Middle River downstream from Old River over baseline conditions (for 100- to 500-year flood events). While this appears to be a sizable increase in flow, note that the 500-year increase of 6,000 cfs over baseline conditions represents a relatively small amount of the total flow in the San Joaquin at Vernalis (over 150,000 cfs).

Scenario 2 showed localized improvements in flow along Paradise Cut that did not extend into other channels in the study area. Similarly, Scenario 1 showed an increase in flow in Middle River, but these effects were localized and did not result in increased flow elsewhere in the system.

# TABLE VI-2
## COMPARISON OF SIMULATED FLOW FOR SCENARIOS IN THE LOWER SAN JOAQUIN AREA

| UNET Index Point | Return Period | Peak Flow / % Change from Baseline | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Baseline | Scenario 1 | | Scenario 2 | | Scenario 3 | |
| | | (cfs) | (cfs) | % | (cfs) | % | (cfs) | % |
| *San Joaquin River at Vernalis* | *10* | 33,196 | 33,196 | 0.00 | 33,202 | 0.02 | 33,225 | 0.09 |
| | *50* | 43,040 | 43,040 | 0.00 | 43,035 | -0.01 | 43,109 | 0.16 |
| | *100* | 68,990 | 68,989 | 0.00 | 68,991 | 0.00 | 69,272 | 0.41 |
| | *200* | 105,147 | 105,147 | 0.00 | 105,170 | 0.02 | 105,657 | 0.48 |
| | *500* | 151,167 | 151,168 | 0.00 | 151,231 | 0.04 | 152,052 | 0.59 |
| *San Joaquin River u/s Paradise Cut* | *10* | 31,497 | 31,497 | 0.00 | 31,538 | 0.13 | 31,558 | 0.19 |
| | *50* | 46,378 | 46,384 | 0.02 | 46,686 | 0.66 | 46,787 | 0.88 |
| | *100* | 64,760 | 64,765 | 0.01 | 64,947 | 0.29 | 65,254 | 0.76 |
| | *200* | 93,835 | 93,849 | 0.02 | 94,472 | 0.68 | 95,412 | 1.68 |
| | *500* | 132,387 | 132,375 | -0.01 | 133,128 | 0.56 | 134,265 | 1.42 |
| *San Joaquin River u/s Old River* | *10* | 25,269 | 25,260 | -0.04 | 24,825 | -1.76 | 24,874 | -1.56 |
| | *50* | 31,655 | 31,650 | -0.02 | 31,221 | -1.37 | 31,328 | -1.03 |
| | *100* | 38,897 | 38,856 | -0.10 | 38,160 | -1.89 | 38,334 | -1.45 |
| | *200* | 47,898 | 47,936 | 0.08 | 47,761 | -0.29 | 47,924 | 0.05 |
| | *500* | 52,723 | 52,665 | -0.11 | 51,691 | -1.96 | 52,003 | -1.36 |
| *San Joaquin River near d/s end of SJRUNET* | *10* | 4,857 | 4,874 | 0.35 | 4,866 | 0.17 | 4,868 | 0.22 |
| | *50* | 5,707 | 5,692 | -0.27 | 5,717 | 0.16 | 5,713 | 0.10 |
| | *100* | 8,906 | 9,122 | 2.43 | 8,834 | -0.81 | 9,055 | 1.67 |
| | *200* | 14,368 | 14,505 | 0.96 | 14,252 | -0.80 | 14,415 | 0.33 |
| | *500* | 19,884 | 20,019 | 0.68 | 19,740 | -0.73 | 19,899 | 0.07 |
| *Old River d/s San Joaquin bifurcation* | *10* | 18,813 | 18,842 | 0.15 | 18,423 | -2.07 | 18,539 | -1.46 |
| | *50* | 22,925 | 22,946 | 0.09 | 22,565 | -1.57 | 22,710 | -0.94 |
| | *100* | 26,752 | 26,775 | 0.09 | 26,442 | -1.16 | 26,706 | -0.17 |
| | *200* | 32,987 | 33,039 | 0.16 | 32,695 | -0.89 | 32,906 | -0.25 |
| | *500* | 33,081 | 33,467 | 1.17 | 32,732 | -1.05 | 32,884 | -0.59 |
| *Old River u/s Middle River bifurcation* | *10* | 15,291 | 15,460 | 1.11 | 15,290 | 0.00 | 15,518 | 1.48 |
| | *50* | 16,212 | 16,313 | 0.62 | 15,880 | -2.05 | 16,098 | -0.71 |
| | *100* | 16,546 | 17,057 | 3.09 | 16,242 | -1.84 | 16,800 | 1.53 |
| | *200* | 17,040 | 17,730 | 4.05 | 16,601 | -2.58 | 17,532 | 2.89 |
| | *500* | 24,656 | 26,091 | 5.82 | 23,966 | -2.80 | 25,914 | 5.10 |
| *Old River near d/s end ofSJRUNET l* | *10* | 4,893 | 4,876 | -0.35 | 4,913 | 0.42 | 4,898 | 0.10 |
| | *50* | 7,801 | 7,738 | -0.81 | 7,715 | -1.11 | 7,621 | -2.32 |
| | *100* | 9,972 | 9,854 | -1.18 | 10,025 | 0.54 | 9,899 | -0.73 |
| | *200* | 13,750 | 13,628 | -0.89 | 13,855 | 0.76 | 13,685 | -0.48 |
| | *500* | 22,038 | 21,781 | -1.16 | 22,218 | 0.82 | 21,963 | -0.34 |
| *Paradise Cut d/s Paradise Weir* | *10* | 7,702 | 7,700 | -0.03 | 8,201 | 6.471 | 8,165 | 6.01 |
| | *50* | 11,771 | 11,769 | -0.02 | 13,011 | 0.53 | 12,803 | 8.77 |
| | *100* | 18,886 | 18,878 | -0.04 | 20,290 | 7.43 | 20,098 | 6.42 |
| | *200* | 25,349 | 25,357 | 0.03 | 28,339 | 11.80 | 28,038 | 10.61 |
| | *500* | 35,703 | 35,740 | 0.10 | 39,965 | 11.94 | 40,085 | 12.27 |
| *Grand Line Canal Near d/s end of SJRUNETl* | *10* | 15,769 | 15,735 | -0.22 | 15,805 | 0.22 | 15,774 | 0.03 |
| | *50* | 21,096 | 20,972 | -0.59 | 20,928 | -0.80 | 20,734 | -1.71 |
| | *100* | 25,687 | 25,443 | -0.95 | 25,795 | 0.42 | 25,533 | -0.60 |
| | *200* | 32,238 | 32,025 | -0.66 | 32,421 | 0.57 | 32,130 | -0.33 |
| | *500* | 47,041 | 46,867 | -0.37 | 47,241 | 0.43 | 47,105 | 0.14 |

**TABLE VI-2 (CONT.)**

| SJRUNET Index Point | Return Period | Peak Flow / % Change from Baseline | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Baseline | Scenario 1 | | Scenario 2 | | Scenario 3 | |
| | | (cfs) | (cfs) | % | (cfs) | % | (cfs) | % |
| *Middle River d/s Old River* | *10* | 1,669 | 1,945 | 16.54 | 1,663 | -0.32 | 2,010 | 20.44 |
| | *50* | 2,433 | 3,000 | 23.31 | 2,445 | 0.47 | 3,025 | 24.33 |
| | *100* | 3,629 | 5,358 | 47.64 | 3,636 | 0.18 | 5,452 | 50.23 |
| | *200* | 4,323 | 6,038 | 39.67 | 4,336 | 0.31 | 6,234 | 44.20 |
| | *500* | 7,598 | 13,115 | 72.62 | 7,823 | 2.97 | 13,434 | 76.82 |
| *Middle River near d/s end of SJRUNET* | *10* | 1,195 | 1,192 | -0.26 | 1,195 | 0.00 | 972 | -18.69 |
| | *50* | 4,306 | 4,697 | 9.08 | 4,262 | -1.01 | 4,753 | 10.38 |
| | *100* | 10,206 | 10,612 | 3.98 | 10,138 | -0.67 | 10,692 | 4.76 |
| | *200* | 15,246 | 15,488 | 1.58 | 15,150 | -0.63 | 15,590 | 2.26 |
| | *500* | 20,775 | 21,198 | 2.04 | 20,676 | -0.47 | 21,391 | 2.96 |

*Note: Simulations reflect existing levee conditions (no levee strengthening).*

## Effects on Stage

Table VI-3 compares the simulated stage of the three scenarios with the baseline condition for the without levee strengthening condition. Model simulations indicate minor impacts on stage in the San Joaquin River for all three scenarios, the largest change (about 1%) occurring just upstream from Paradise Cut for Scenarios 2 and 3. On Old River, Scenario 2 would have the greatest impact on stage, also about a 1% decrease over existing conditions. Scenarios 2 and 3 would result in 2% to 3% decreases in stage on Paradise Cut, just downstream from the weir, representing the most significant stage impact observed in the model simulations. Middle River and the Grant Line Canal would show negligible changes in stage over baseline for all scenarios and storm events.

Water surface profiles for the baseline conditions and three scenarios are shown in Figures VI-1 through VI-4. The profiles illustrate the relatively insignificant changes in stage that would be observed between the baseline and three alternative scenarios.

**TABLE VI-3**
**COMPARISON OF SIMULATED STAGE FOR SCENARIOS IN THE LOWER SAN JOAQUIN AREA**

| SJRUNET Index Point | Return Period | Stage / % Change from Baseline | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Baseline | Scenario 1 | | Scenario 2 | | Scenario 3 | |
| | | (ft) | (ft) | % | (ft) | % | (ft) | % |
| *San Joaquin River at Vernalis* | *10* | 28.77 | 28.77 | 0.00 | 28.76 | -0.02 | 28.70 | -0.24 |
| | *50* | 31.62 | 31.62 | 0.00 | 31.61 | -0.03 | 31.50 | -0.38 |
| | *100* | 35.78 | 35.78 | 0.00 | 35.77 | -0.03 | 35.64 | -0.41 |
| | *200* | 40.08 | 40.08 | 0.00 | 40.07 | -0.02 | 39.92 | -0.41 |
| | *500* | 45.83 | 45.83 | 0.00 | 45.80 | -0.05 | 45.62 | -0.46 |
| *San Joaquin River u/s Paradise Cut* | *10* | 19.02 | 19.02 | -0.01 | 18.86 | -0.85 | 18.84 | -0.93 |
| | *50* | 21.24 | 21.24 | 0.00 | 21.10 | -0.66 | 21.07 | -0.80 |
| | *100* | 23.87 | 23.86 | -0.03 | 23.65 | -0.92 | 23.59 | -1.15 |
| | *200* | 26.11 | 26.11 | -0.03 | 26.01 | -0.41 | 25.94 | -0.65 |
| | *500* | 30.51 | 30.50 | -0.02 | 30.15 | -1.19 | 30.18 | -1.07 |
| *San Joaquin River u/s Old River* | *10* | 13.01 | 13.02 | 0.02 | 12.93 | -0.64 | 12.91 | -0.79 |
| | *50* | 14.34 | 14.33 | -0.05 | 14.32 | -0.13 | 14.29 | -0.36 |
| | *100* | 15.60 | 15.60 | 0.04 | 15.53 | -0.42 | 15.54 | -0.35 |
| | *200* | 15.95 | 15.98 | 0.16 | 15.89 | -0.39 | 15.93 | -0.11 |
| | *500* | 19.33 | 19.32 | -0.07 | 19.26 | -0.40 | 19.26 | -0.38 |
| *San Joaquin River near d/s end of SJRUNET* | *10* | 7.45 | 7.46 | 0.15 | 7.46 | 0.08 | 7.46 | 0.09 |
| | *50* | 8.96 | 8.95 | -0.04 | 8.96 | 0.01 | 8.96 | 0.01 |
| | *100* | 9.51 | 9.53 | 0.24 | 9.50 | -0.08 | 9.53 | 0.17 |
| | *200* | 10.10 | 10.12 | 0.16 | 10.09 | -0.13 | 10.11 | 0.06 |
| | *500* | 10.72 | 10.73 | 0.14 | 10.70 | -0.15 | 10.72 | 0.01 |
| *Old River d/s San Joaquin bifurcation* | *10* | 13.01 | 13.02 | 0.02 | 12.93 | -0.64 | 12.91 | -0.79 |
| | *50* | 14.34 | 14.33 | -0.05 | 14.32 | -0.13 | 14.29 | -0.36 |
| | *100* | 15.60 | 15.60 | 0.04 | 15.53 | -0.42 | 15.54 | -0.35 |
| | *200* | 15.95 | 15.98 | 0.16 | 15.89 | -0.39 | 15.93 | -0.11 |
| | *500* | 19.33 | 19.32 | -0.07 | 19.26 | -0.40 | 19.26 | -0.38 |
| *Old River u/s Middle River bifurcation* | *10* | 10.41 | 10.38 | -0.30 | 10.40 | -0.11 | 10.35 | -0.57 |
| | *50* | 12.08 | 12.04 | -0.35 | 12.05 | -0.26 | 12.00 | -0.71 |
| | *100* | 13.32 | 13.23 | -0.69 | 13.32 | -0.04 | 13.23 | -0.70 |
| | *200* | 14.67 | 14.61 | -0.42 | 14.67 | 0.03 | 14.61 | -0.42 |
| | *500* | 17.69 | 17.51 | -1.02 | 17.69 | 0.01 | 17.52 | -0.96 |
| *Old River near d/s end of SJRUNET* | *10* | 7.52 | 7.51 | -0.12 | 7.53 | 0.13 | 7.52 | 0.03 |
| | *50* | 8.88 | 8.87 | -0.12 | 8.86 | -0.17 | 8.85 | -0.35 |
| | *100* | 9.23 | 9.22 | -0.14 | 9.24 | 0.06 | 9.22 | -0.09 |
| | *200* | 9.57 | 9.57 | -0.07 | 9.58 | 0.06 | 9.57 | -0.04 |
| | *500* | 10.05 | 10.03 | -0.15 | 10.06 | 0.10 | 10.04 | -0.05 |
| *Paradise Cut d/s Paradise Weir* | *10* | 17.40 | 17.40 | -0.01 | 16.89 | -2.93 | 16.87 | -3.06 |
| | *50* | 19.18 | 19.18 | -0.01 | 18.94 | -1.27 | 18.91 | -1.40 |
| | *100* | 21.17 | 21.17 | -0.03 | 20.82 | -1.66 | 20.77 | -1.91 |
| | *200* | 22.99 | 22.97 | -0.06 | 22.56 | -1.85 | 22.52 | -2.04 |
| | *500* | 26.56 | 26.55 | -0.04 | 25.88 | -2.57 | 25.87 | -2.61 |
| *Grand Line Canal Near d/s end of SJRUNET* | *10* | 7.42 | 7.41 | -0.15 | 7.44 | 0.15 | 7.43 | 0.01 |
| | *50* | 8.88 | 8.87 | -0.11 | 8.86 | -0.16 | 8.85 | -0.34 |
| | *100* | 9.25 | 9.23 | -0.18 | 9.26 | 0.08 | 9.24 | -0.12 |
| | *200* | 9.59 | 9.58 | -0.07 | 9.59 | 0.05 | 9.58 | -0.03 |
| | *500* | 10.04 | 10.03 | -0.06 | 10.04 | 0.06 | 10.04 | 0.02 |

## TABLE VI-3 (CONT.)

| SJRUNET Index Point | Return Period | Stage / % Change from Baseline | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Baseline | Scenario 1 | | Scenario 2 | | Scenario 3 | |
| | | (ft) | (ft) | % | (ft) | % | (ft) | % |
| *Middle River d/s Old River* | *10* | 10.41 | 10.38 | -0.30 | 10.40 | -0.11 | 10.35 | -0.57 |
| | *50* | 12.08 | 12.04 | -0.35 | 12.05 | -0.26 | 12.00 | -0.71 |
| | *100* | 13.32 | 13.23 | -0.69 | 13.32 | -0.04 | 13.23 | -0.70 |
| | *200* | 14.67 | 14.61 | -0.42 | 14.67 | 0.03 | 14.61 | -0.42 |
| | *500* | 17.69 | 17.51 | -1.02 | 17.69 | 0.01 | 17.52 | -0.96 |
| *Middle River near d/s end of SJRUNETl* | *10* | 6.27 | 6.27 | 0.00 | 6.27 | 0.00 | 6.27 | 0.00 |
| | *50* | 7.07 | 7.16 | 1.27 | 7.06 | -0.14 | 7.17 | 1.46 |
| | *100* | 7.62 | 7.64 | 0.29 | 7.61 | -0.05 | 7.64 | 0.34 |
| | *200* | 7.90 | 7.92 | 0.19 | 7.90 | -0.09 | 7.93 | 0.28 |
| | *500* | 8.26 | 8.28 | 0.33 | 8.25 | -0.07 | 8.30 | 0.47 |

*Note: Simulations reflect existing levee conditions (no levee strengthening).*

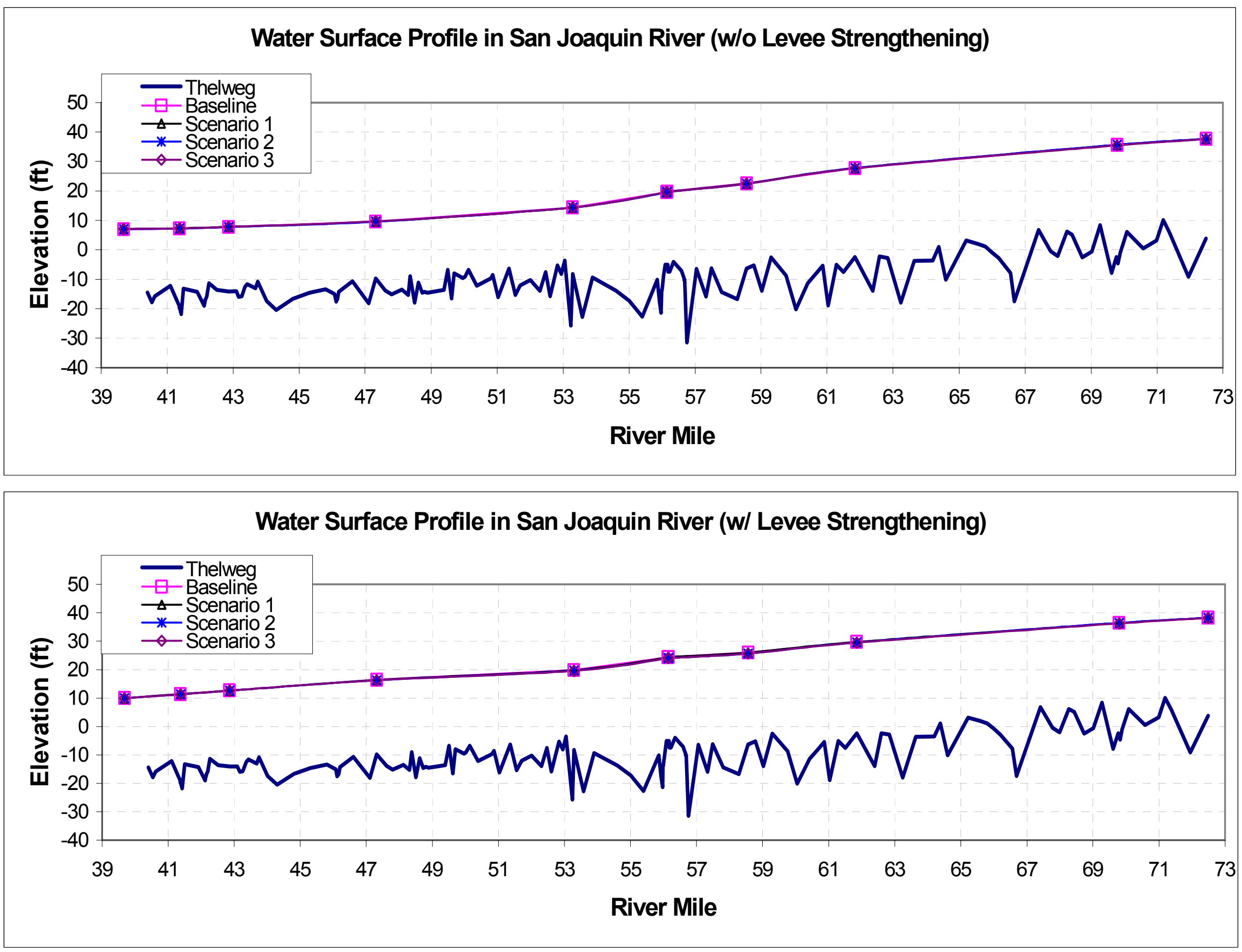



**FIGURE VI-1 WATER SURFACE PROFILES – SAN JOAQUIN RIVER**

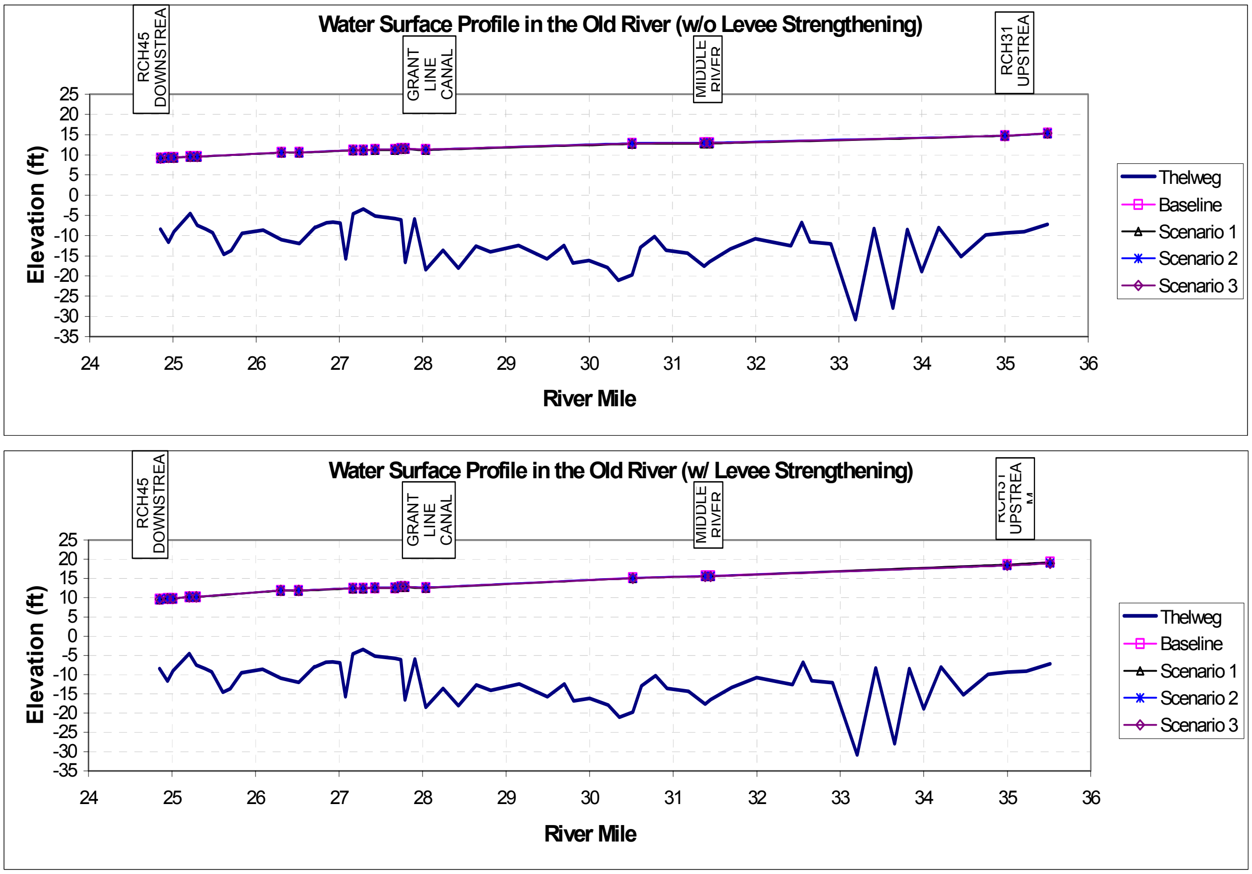
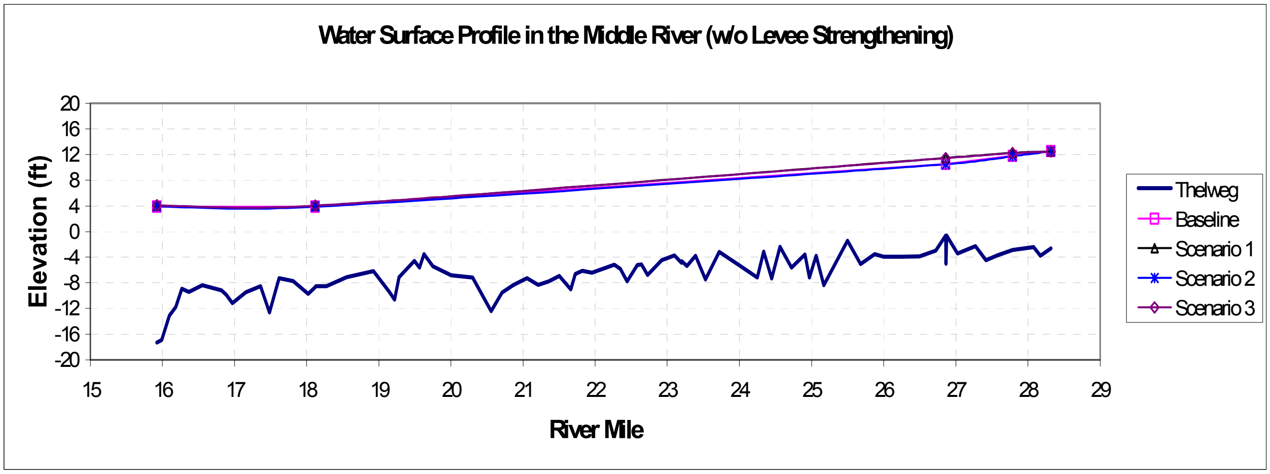



**FIGURE VI-2 WATER SURFACE PROFILES – OLD RIVER**



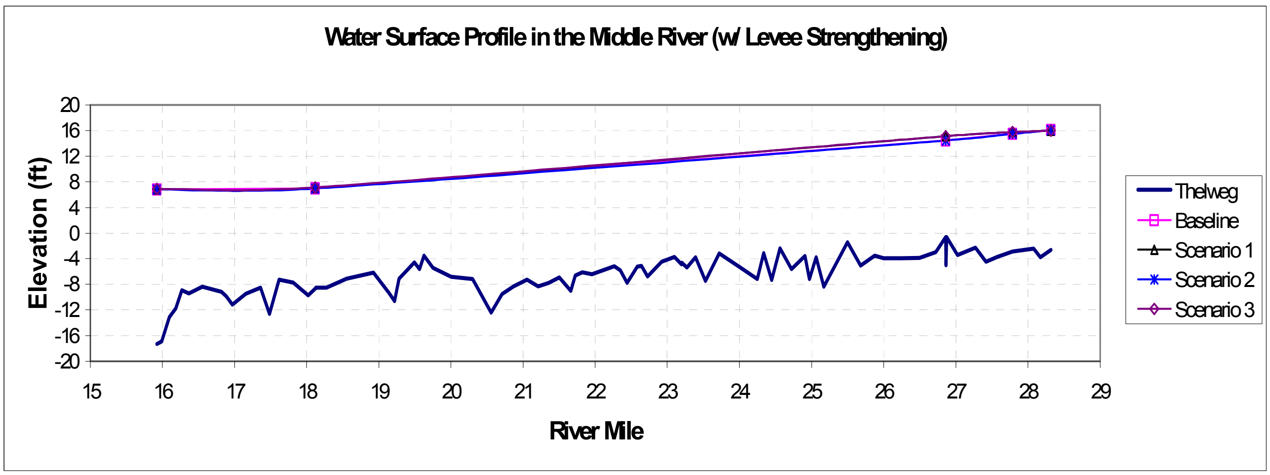
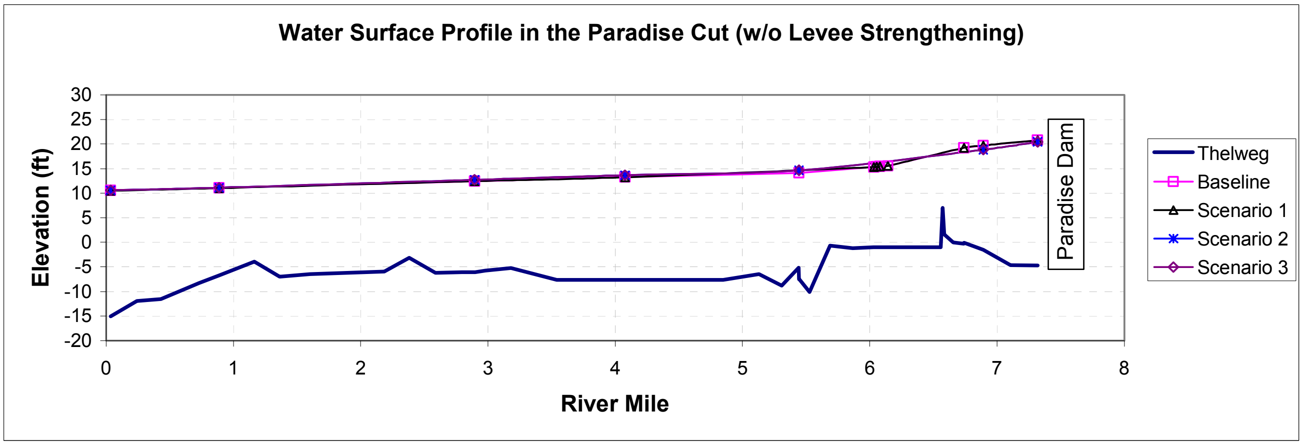




**FIGURE VI-3 WATER SURFACE PROFILES – MIDDLE RIVER**



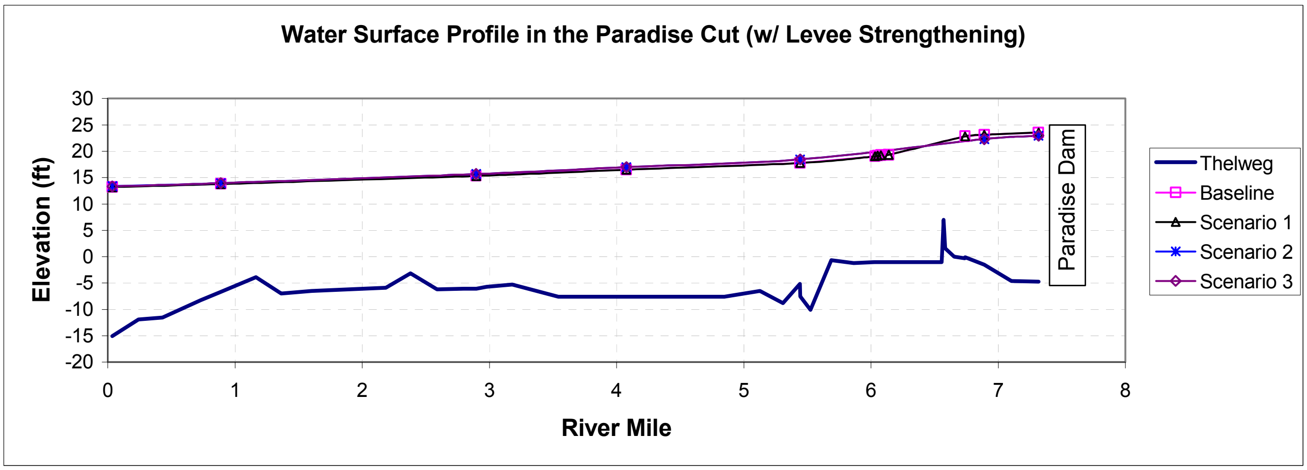




FIGURE VI-4 WATER SURFACE PROFILES – PARADISE CUT

## Effects of Levee Strengthening

The levee strengthening component modeled for the baseline and three scenarios provided for levee failure only by overtopping at the current top of levee elevations, rather than failure by breach or piping at the lower, likely failure point. The result was significantly lower volumes of overflow from the channels into floodplain storage areas. Levee strengthening would increase flow out of the SJRUNET modeling area because a large amount of water was prevented from leaving the channels. The volume of water out of the downstream model boundary would increase by 18% to 40% for the various storm events modeled.

The SJRUNET model indicated a slight decrease in the flow volume entering the study area. This could be a result of increased river stage in the Lower San Joaquin River and its distributaries with the levee strengthening component. The higher stage could have a backwater effect on incoming flow in the San Joaquin River, resulting in the slightly lower flows observed entering the study area. However, this decrease in flow was insignificant in comparison to the increase in flow observed at the downstream boundary conditions. Table VI-4 compares simulated flow baseline and scenario with- and without levee strengthening.

**TABLE VI-4**
**COMPARISON OF SIMULATED FLOW, WITH- AND WITHOUT LEVEE STRENGTHENING – BASELINE AND SCENARIO 1**

| SJRUNET Index Point | Return Period | Flow / % Change | | | | | |
|---|---|---|---|---|---|---|---|
| | | *Baseline* | | | *Scenario 1* | | |
| | | w/o levee strength. *(cfs)* | w/ levee strength. *(cfs)* | difference *%* | w/o levee strength. *(cfs)* | w/ levee strength. *(cfs)* | difference *%* |
| *San Joaquin River at Vernalis* | *10* | 33,196 | 32,950 | -0.74 | 33,196 | 32,950 | -0.74 |
| | *50* | 43,040 | 44,916 | 4.36 | 43,040 | 44,917 | 4.36 |
| | *100* | 68,990 | 71,257 | 3.29 | 68,989 | 71,261 | 3.29 |
| | *200* | 105,147 | 107,840 | 2.56 | 105,147 | 107,854 | 2.57 |
| | *500* | 151,167 | 151,313 | 0.10 | 151,168 | 151,547 | 0.25 |
| *San Joaquin River u/s Paradise Cut* | *10* | 31,497 | 32,929 | 4.55 | 31,497 | 32,929 | 4.55 |
| | *50* | 46,378 | 44,756 | -3.50 | 46,384 | 44,758 | -3.51 |
| | *100* | 64,760 | 64,857 | 0.15 | 64,765 | 64,869 | 0.16 |
| | *200* | 93,835 | 90,207 | -3.87 | 93,849 | 90,236 | -3.85 |
| | *500* | 132,387 | 133,476 | 0.82 | 132,375 | 133,597 | 0.92 |
| *San Joaquin u/s Old River* | *10* | 25,269 | 25,051 | -0.86 | 25,260 | 25,064 | -0.78 |
| | *50* | 31,655 | 32,819 | 3.68 | 31,650 | 32,834 | 3.74 |
| | *100* | 38,897 | 45,715 | 17.53 | 38,856 | 45,741 | 17.72 |
| | *200* | 47,898 | 60,709 | 26.75 | 47,936 | 61,117 | 27.50 |
| | *500* | 52,723 | 79,130 | 50.09 | 52,665 | 79,403 | 50.77 |
| *San Joaquin near d/s end of SJRUNET* | *10* | 4,857 | 7,537 | 55.18 | 4,874 | 7,503 | 53.94 |
| | *50* | 5,707 | 10,392 | 82.09 | 5,692 | 10,356 | 81.94 |
| | *100* | 8,906 | 13,239 | 48.65 | 9,122 | 13,220 | 44.92 |
| | *200* | 14,368 | 14,989 | 4.32 | 14,505 | 14,806 | 2.08 |
| | *500* | 19,884 | 20,400 | 2.60 | 20,019 | 21,882 | 9.31 |
| *Old River d/s San Joaquin bifurcation* | *10* | 18,813 | 18,938 | 0.66 | 18,842 | 18,988 | 0.77 |
| | *50* | 22,925 | 24,757 | 7.99 | 22,946 | 24,808 | 8.11 |
| | *100* | 26,752 | 33,966 | 26.97 | 26,775 | 34,044 | 27.15 |
| | *200* | 32,987 | 43,647 | 32.32 | 33,039 | 45,031 | 36.30 |
| | *500* | 33,081 | 54,718 | 65.41 | 33,467 | 55,813 | 66.77 |
| *Old River u/s Middle River bifurcation* | *10* | 15,291 | 18,937 | 23.84 | 15,460 | 18,987 | 22.81 |
| | *50* | 16,212 | 24,754 | 52.69 | 16,313 | 24,805 | 52.06 |
| | *100* | 16,546 | 33,963 | 105.26 | 17,057 | 34,041 | 99.57 |
| | *200* | 17,040 | 40,483 | 137.58 | 17,730 | 43,658 | 146.24 |
| | *500* | 24,656 | 45,258 | 83.56 | 26,091 | 49,663 | 90.35 |
| *Old River near d/s end of SJRUNET* | *10* | 4,893 | 6,379 | 30.37 | 4,876 | 6,287 | 28.94 |
| | *50* | 7,801 | 9,470 | 21.39 | 7,738 | 9,358 | 20.94 |
| | *100* | 9,972 | 14,528 | 45.69 | 9,854 | 14,392 | 46.05 |
| | *200* | 13,750 | 18,334 | 33.34 | 13,628 | 16,250 | 19.24 |
| | *500* | 22,038 | 25,607 | 16.19 | 21,781 | 24,825 | 13.98 |
| *Paradise Cut d/s Paradise Weir* | *10* | 7,702 | 8,069 | 4.76 | 7,700 | 8,056 | 4.62 |
| | *50* | 11,771 | 12,102 | 2.81 | 11,769 | 12,089 | 2.72 |
| | *100* | 18,886 | 18,728 | -0.84 | 18,878 | 18,723 | -0.82 |
| | *200* | 25,349 | 26,814 | 5.78 | 25,357 | 26,636 | 5.04 |
| | *500* | 35,703 | 40,319 | 12.93 | 35,740 | 40,350 | 12.90 |

## TABLE VI-4 (CONT.)

| **SJRUNET Index Point** | **Return Period** | **Flow / % Change** | | | | | |
|---|---|---|---|---|---|---|---|
| | | ***Baseline*** | | | ***Scenario 1*** | | |
| | | **w/o levee strength.** *(cfs)* | **w/ levee strength.** *(cfs)* | **difference** *%* | **w/o levee strength.** *(cfs)* | **w/ levee strength.** *(cfs)* | **difference** *%* |
| *Grand Line Canal Near d/s end of SJRUNET l* | *10* | 15,769 | 18,538 | 17.56 | 15,735 | 18,370 | 16.75 |
| | *50* | 21,096 | 24,407 | 15.69 | 20,972 | 24,184 | 15.32 |
| | *100* | 25,687 | 33,789 | 31.54 | 25,443 | 33,542 | 31.83 |
| | *200* | 32,238 | 40,455 | 25.49 | 32,025 | 36,838 | 15.03 |
| | *500* | 47,041 | 52,005 | 10.55 | 46,867 | 50,799 | 8.39 |
| *Middle River d/s Old River* | *10* | 1,669 | 2,080 | 24.63 | 1,945 | 2,377 | 22.21 |
| | *50* | 2,433 | 2,956 | 21.50 | 3,000 | 3,328 | 10.93 |
| | *100* | 3,629 | 4,355 | 20.01 | 5,358 | 4,811 | -10.21 |
| | *200* | 4,323 | 5,461 | 26.32 | 6,038 | 17,712 | 193.34 |
| | *500* | 7,598 | 7,256 | -4.50 | 13,115 | 20,033 | 52.75 |
| *Middle River near d/s end of SJRUNE* | *10* | 1,195 | 2,080 | 74.06 | 972 | 2,233 | 129.73 |
| | *50* | 4,306 | 2,498 | -41.99 | 4,697 | 2,667 | -43.22 |
| | *100* | 10,206 | 3,132 | -69.31 | 10,612 | 3,338 | -68.55 |
| | *200* | 15,246 | 3,549 | -76.72 | 15,488 | 8,291 | -46.47 |
| | *500* | 20,775 | 12,574 | -39.48 | 21,198 | 13,932 | -34.28 |

**TABLE VI-5**
**COMPARISON OF SIMULATED FLOW, WITH- AND WITHOUT LEVEE STRENGTHENING –SCENARIO 2 AND SCENARIO 3**

| SJRUNET Index Point | Return Period | Flow / % Change | | | | | |
|---|---|---|---|---|---|---|---|
| | | *Scenario 2* | | | *Scenario 3* | | |
| | | w/o levee strength. (cfs) | w/ levee strength. (cfs) | difference % | w/o levee strength. (cfs) | w/ levee strength. (cfs) | difference % |
| *San Joaquin River at Vernalis* | *10* | 33,202 | 32,952 | -0.75 | 33,225 | 32,934 | -0.88 |
| | *50* | 43,035 | 44,948 | 4.45 | 43,109 | 45,068 | 4.54 |
| | *100* | 68,991 | 71,294 | 3.34 | 69,272 | 71,517 | 3.24 |
| | *200* | 105,170 | 107,884 | 2.58 | 105,657 | 108,391 | 2.59 |
| | *500* | 151,231 | 151,784 | 0.37 | 152,052 | 152,277 | 0.15 |
| *San Joaquin River u/s Paradise Cut* | *10* | 31,538 | 32,932 | 4.42 | 31,558 | 32,915 | 4.30 |
| | *50* | 46,686 | 44,798 | -4.04 | 46,787 | 44,913 | -4.01 |
| | *100* | 64,947 | 65,263 | 0.49 | 65,254 | 65,806 | 0.85 |
| | *200* | 94,472 | 90,661 | -4.03 | 95,412 | 91,142 | -4.48 |
| | *500* | 133,128 | 134,356 | 0.92 | 134,265 | 135,129 | 0.64 |
| *San Joaquin River u/s Old River* | *10* | 24,825 | 24,447 | -1.52 | 24,874 | 24,495 | -1.52 |
| | *50* | 31,221 | 31,754 | 1.71 | 31,328 | 31,937 | 1.94 |
| | *100* | 38,160 | 44,261 | 15.99 | 38,334 | 44,743 | 16.72 |
| | *200* | 47,761 | 58,542 | 22.57 | 47,924 | 58,883 | 22.87 |
| | *500* | 51,691 | 77,854 | 50.61 | 52,003 | 78,338 | 50.64 |
| *San Joaquin near d/s end of SJRUNET* | *10* | 4,866 | 7,455 | 53.21 | 4,868 | 7,411 | 52.24 |
| | *50* | 5,717 | 10,192 | 78.28 | 5,713 | 10,130 | 77.31 |
| | *100* | 8,834 | 13,103 | 48.32 | 9,055 | 13,072 | 44.36 |
| | *200* | 14,252 | 14,870 | 4.34 | 14,415 | 14,832 | 2.89 |
| | *500* | 19,740 | 20,101 | 1.83 | 19,899 | 20,073 | 0.87 |
| *Old River d/s San Joaquin bifurcation* | *10* | 18,423 | 18,446 | 0.12 | 18,539 | 18,559 | 0.11 |
| | *50* | 22,565 | 23,893 | 5.89 | 22,710 | 24,140 | 6.30 |
| | *100* | 26,442 | 32,852 | 24.24 | 26,706 | 33,415 | 25.12 |
| | *200* | 32,695 | 42,132 | 28.86 | 32,906 | 42,692 | 29.74 |
| | *500* | 32,732 | 53,719 | 64.12 | 32,884 | 54,457 | 65.60 |
| *Old River u/s Middle River bifurcation* | *10* | 15,290 | 18,445 | 20.63 | 15,518 | 18,557 | 19.58 |
| | *50* | 15,880 | 23,891 | 50.45 | 16,098 | 24,136 | 49.93 |
| | *100* | 16,242 | 32,848 | 102.2 | 16,800 | 33,411 | 98.88 |
| | *200* | 16,601 | 39,321 | 136.8 | 17,532 | 40,085 | 128.64 |
| | *500* | 23,966 | 44,051 | 83.81 | 25,914 | 45,333 | 74.94 |
| *Old River near d/s end of SJRUNET* | *10* | 4,913 | 6,426 | 30.80 | 4,898 | 6,304 | 28.71 |
| | *50* | 7,715 | 9,563 | 23.95 | 7,621 | 9,432 | 23.76 |
| | *100* | 10,025 | 14,919 | 48.82 | 9,899 | 14,839 | 49.90 |
| | *200* | 13,855 | 19,432 | 40.25 | 13,685 | 19,261 | 40.75 |
| | *500* | 22,218 | 25,786 | 16.06 | 21,963 | 25,500 | 16.10 |
| *Paradise Cut d/s Paradise Weir* | *10* | 8,201 | 8,677 | 5.80 | 8,165 | 8,612 | 5.47 |
| | *50* | 13,011 | 13,210 | 1.53 | 12,803 | 13,140 | 2.63 |
| | *100* | 20,290 | 20,932 | 3.16 | 20,098 | 20,968 | 4.33 |
| | *200* | 28,339 | 30,417 | 7.33 | 28,038 | 30,392 | 8.40 |
| | *500* | 39,965 | 45,012 | 12.63 | 40,085 | 44,979 | 12.21 |

## TABLE VI-5 (CONT.)

| **SJRUNET Index Point** | **Return Period** | **Flow / % Change** | | | | | |
|---|---|---|---|---|---|---|---|
| | | ***Scenario 2*** | | | ***Scenario 3*** | | |
| | | **w/o levee strength.** *(cfs)* | **w/ levee strength.** *(cfs)* | **difference** *%* | **w/o levee strength.** *(cfs)* | **w/ levee strength.** *(cfs)* | **difference** *%* |
| *Grand Line Canal Near d/s end of SJRUNET* | *10* | 15,805 | 18,622 | 17.82 | 15,774 | 18,398 | 16.63 |
| | *50* | 20,928 | 24,586 | 17.48 | 20,734 | 24,328 | 17.33 |
| | *100* | 25,795 | 34,483 | 33.68 | 25,533 | 34,339 | 34.49 |
| | *200* | 32,421 | 42,264 | 30.36 | 32,130 | 41,980 | 30.66 |
| | *500* | 47,241 | 52,277 | 10.66 | 47,105 | 51,840 | 10.05 |
| *Middle River d/s Old River* | *10* | 1,663 | 2,065 | 24.17 | 2,010 | 2,458 | 22.29 |
| | *50* | 2,445 | 2,929 | 19.80 | 3,025 | 3,491 | 15.40 |
| | *100* | 3,636 | 4,358 | 19.86 | 5,452 | 5,180 | -4.99 |
| | *200* | 4,336 | 5,539 | 27.74 | 6,234 | 6,648 | 6.64 |
| | *500* | 7,823 | 7,388 | -5.56 | 13,434 | 9,318 | -30.64 |
| *Middle River near d/s end of SJRUNET* | *10* | 972 | 2,065 | 112.45 | 972 | 2,298 | 136.42 |
| | *50* | 4,262 | 2,485 | -41.69 | 4,753 | 2,776 | -41.59 |
| | *100* | 10,138 | 3,133 | -69.10 | 10,692 | 3,551 | -66.79 |
| | *200* | 15,150 | 3,840 | -74.65 | 15,590 | 4,572 | -70.67 |
| | *500* | 20,676 | 12,117 | -41.40 | 21,391 | 12,792 | -40.20 |

## TABLE VI-6

## COMPARISON OF SIMULATED PEAK STAGE, WITH- AND WITHOUT LEVEE STRENGTHENGING – BASELINE AND SCENARIO 1

| SJRUNET Index Point | Return Period | Stage / % Change | | | | | |
|---|---|---|---|---|---|---|---|
| | | ***Baseline*** | | | ***Scenario 1*** | | |
| | | **w/o levee strength.** *(ft)* | **w/ levee strength.** *(ft)* | **difference** *%* | **w/o levee strength.** *(ft)* | **w/ levee strength.** *(ft)* | **difference** *%* |
| *San Joaquin River at Vernalis* | *10* | 28.77 | 29.39 | 2.16 | 28.77 | 29.38 | 2.12 |
| | *50* | 31.62 | 32.09 | 1.49 | 31.62 | 32.08 | 1.45 |
| | *100* | 35.78 | 36.47 | 1.93 | 35.78 | 36.47 | 1.93 |
| | *200* | 40.08 | 40.10 | 0.05 | 40.08 | 40.10 | 0.05 |
| | *500* | 45.83 | 46.13 | 0.65 | 45.83 | 46.14 | 0.68 |
| *San Joaquin River u/s Paradise Cut* | *10* | 19.02 | 19.47 | 2.37 | 19.02 | 19.46 | 2.31 |
| | *50* | 21.24 | 22.27 | 4.85 | 21.24 | 22.26 | 4.80 |
| | *100* | 23.87 | 26.09 | 9.30 | 23.86 | 26.08 | 9.30 |
| | *200* | 26.11 | 29.70 | 13.75 | 26.11 | 29.63 | 13.48 |
| | *500* | 30.51 | 33.53 | 9.90 | 30.50 | 33.53 | 9.93 |
| *San Joaquin River u/s Old River* | *10* | 13.01 | 14.32 | 10.07 | 13.02 | 14.28 | 9.68 |
| | *50* | 14.34 | 16.70 | 16.46 | 14.33 | 16.67 | 16.33 |
| | *100* | 15.60 | 19.90 | 27.56 | 15.60 | 19.87 | 27.37 |
| | *200* | 15.95 | 22.16 | 38.93 | 15.98 | 21.82 | 36.55 |
| | *500* | 19.33 | 23.79 | 23.07 | 19.32 | 23.69 | 22.62 |
| *San Joaquin River near d/s end of SJRUNET* | *10* | 7.45 | 9.33 | 25.23 | 7.46 | 9.32 | 24.93 |
| | *50* | 8.96 | 9.67 | 7.92 | 8.95 | 9.67 | 8.04 |
| | *100* | 9.51 | 9.98 | 4.94 | 9.53 | 9.98 | 4.72 |
| | *200* | 10.10 | 10.17 | 0.69 | 10.12 | 10.15 | 0.30 |
| | *500* | 10.72 | 10.78 | 0.56 | 10.73 | 10.94 | 1.96 |
| *Old River d/s San Joaquin bifurcation* | *10* | 13.01 | 14.32 | 10.07 | 13.02 | 14.28 | 9.68 |
| | *50* | 14.34 | 16.70 | 16.46 | 14.33 | 16.67 | 16.33 |
| | *100* | 15.60 | 19.90 | 27.56 | 15.60 | 19.87 | 27.37 |
| | *200* | 15.95 | 22.16 | 38.93 | 15.98 | 21.82 | 36.55 |
| | *500* | 19.33 | 23.79 | 23.07 | 19.32 | 23.69 | 22.62 |
| *Old River u/s Middle River bifurcation* | *10* | 10.41 | 11.82 | 13.54 | 10.38 | 11.73 | 13.01 |
| | *50* | 12.08 | 13.70 | 13.41 | 12.04 | 13.62 | 13.12 |
| | *100* | 13.32 | 16.16 | 21.32 | 13.23 | 16.08 | 21.54 |
| | *200* | 14.67 | 17.75 | 21.00 | 14.61 | 16.59 | 13.55 |
| | *500* | 17.69 | 19.40 | 9.67 | 17.51 | 19.09 | 9.02 |
| *Old River near d/s end of SJRUNET* | *10* | 7.52 | 8.29 | 10.24 | 7.51 | 8.25 | 9.85 |
| | *50* | 8.88 | 9.17 | 3.27 | 8.87 | 9.15 | 3.16 |
| | *100* | 9.23 | 9.62 | 4.23 | 9.22 | 9.61 | 4.23 |
| | *200* | 9.57 | 9.83 | 2.72 | 9.57 | 9.72 | 1.57 |
| | *500* | 10.05 | 10.25 | 1.99 | 10.03 | 10.21 | 1.79 |
| *Paradise Cut d/s Paradise Weir* | *10* | 17.40 | 17.84 | 2.53 | 17.40 | 17.82 | 2.41 |
| | *50* | 19.18 | 20.29 | 5.79 | 19.18 | 20.28 | 5.74 |
| | *100* | 21.17 | 23.58 | 11.38 | 21.17 | 23.57 | 11.34 |
| | *200* | 22.99 | 26.56 | 15.53 | 22.97 | 26.50 | 15.37 |
| | *500* | 26.56 | 29.34 | 10.47 | 26.55 | 29.34 | 10.51 |
| *Grand Line Canal Near d/s end of SJRUNETl* | *10* | 7.42 | 8.29 | 11.73 | 7.41 | 8.23 | 11.07 |
| | *50* | 8.88 | 9.16 | 3.15 | 8.87 | 9.14 | 3.04 |
| | *100* | 9.25 | 9.63 | 4.11 | 9.23 | 9.62 | 4.23 |
| | *200* | 9.59 | 9.84 | 2.61 | 9.58 | 9.73 | 1.57 |
| | *500* | 10.04 | 10.19 | 1.49 | 10.03 | 10.15 | 1.20 |

## TABLE VI-6 (CONT.)

| SJRUNET Index Point | Return Period | Stage / % Change | | | | | |
|---|---|---|---|---|---|---|---|
| | | ***Baseline*** | | | ***Scenario 1*** | | |
| | | **w/o levee strength.** *(ft)* | **w/ levee strength.** *(ft)* | **difference** *%* | **w/o levee strength.** *(ft)* | **w/ levee strength.** *(ft)* | **difference** *%* |
| *Middle River d/s Old River* | *10* | 10.41 | 11.82 | 13.54 | 10.38 | 11.73 | 13.01 |
| | *50* | 12.08 | 13.70 | 13.41 | 12.04 | 13.62 | 13.12 |
| | *100* | 13.32 | 16.16 | 21.32 | 13.23 | 16.08 | 21.54 |
| | *200* | 14.67 | 17.75 | 21.00 | 14.61 | 16.59 | 13.55 |
| | *500* | 17.69 | 19.40 | 9.67 | 17.51 | 19.09 | 9.02 |
| *Middle River near d/s end of SJRUNET* | *10* | 6.27 | 6.55 | 4.47 | 6.27 | 6.59 | 5.10 |
| | *50* | 7.07 | 6.65 | -5.94 | 7.16 | 6.69 | -6.56 |
| | *100* | 7.62 | 6.80 | -10.76 | 7.64 | 6.84 | -10.47 |
| | *200* | 7.90 | 6.89 | -12.78 | 7.92 | 7.50 | -5.30 |
| | *500* | 8.26 | 7.74 | -6.30 | 8.28 | 7.82 | -5.56 |

## TABLE VI-7

## COMPARISON OF SIMULATED PEAK STAGE, WITH- AND WITHOUT LEVEE STRENGTHENGING –SCENARIO 2 AND SCENARIO 3

| SJRUNET Index Point | Return Period | Stage / % Change | | | | | |
|---|---|---|---|---|---|---|---|
| | | Scenario 2 | | | Scenario 3 | | |
| | | w/o levee strength. (ft) | w/ levee strength. (ft) | difference % | w/o levee strength. (ft) | w/ levee strength. (ft) | difference % |
| San Joaquin River at Vernalis | 10 | 28.76 | 29.37 | 2.12 | 28.70 | 29.27 | 1.99 |
| | 50 | 31.61 | 32.06 | 1.42 | 31.50 | 31.95 | 1.43 |
| | 100 | 35.77 | 36.44 | 1.87 | 35.64 | 36.31 | 1.88 |
| | 200 | 40.07 | 40.07 | 0.00 | 39.92 | 39.91 | -0.03 |
| | 500 | 45.80 | 46.09 | 0.63 | 45.62 | 45.90 | 0.61 |
| San Joaquin River u/s Paradise Cut | 10 | 18.86 | 19.26 | 2.12 | 18.84 | 19.22 | 2.02 |
| | 50 | 21.10 | 21.95 | 4.03 | 21.07 | 21.92 | 4.03 |
| | 100 | 23.65 | 25.74 | 8.84 | 23.59 | 25.76 | 9.20 |
| | 200 | 26.01 | 29.20 | 12.26 | 25.94 | 29.21 | 12.61 |
| | 500 | 30.15 | 33.23 | 10.22 | 30.18 | 33.25 | 10.17 |
| San Joaquin River u/s Old River | 10 | 12.93 | 14.19 | 9.74 | 12.91 | 14.12 | 9.37 |
| | 50 | 14.32 | 16.50 | 15.22 | 14.29 | 16.44 | 15.05 |
| | 100 | 15.53 | 19.70 | 26.85 | 15.54 | 19.66 | 26.51 |
| | 200 | 15.89 | 21.92 | 37.95 | 15.93 | 21.84 | 37.10 |
| | 500 | 19.26 | 23.76 | 23.36 | 19.26 | 23.73 | 23.21 |
| San Joaquin River near d/s end of SJRUNET | 10 | 7.46 | 9.31 | 24.80 | 7.46 | 9.30 | 24.66 |
| | 50 | 8.96 | 9.65 | 7.70 | 8.96 | 9.64 | 7.59 |
| | 100 | 9.50 | 9.96 | 4.84 | 9.53 | 9.96 | 4.51 |
| | 200 | 10.09 | 10.16 | 0.69 | 10.11 | 10.16 | 0.49 |
| | 500 | 10.70 | 10.74 | 0.37 | 10.72 | 10.74 | 0.19 |
| Old River d/s San Joaquin bifurcation | 10 | 12.93 | 14.19 | 9.74 | 12.91 | 14.12 | 9.37 |
| | 50 | 14.32 | 16.50 | 15.22 | 14.29 | 16.44 | 15.05 |
| | 100 | 15.53 | 19.70 | 26.85 | 15.54 | 19.66 | 26.51 |
| | 200 | 15.89 | 21.92 | 37.95 | 15.93 | 21.84 | 37.10 |
| | 500 | 19.26 | 23.76 | 23.36 | 19.26 | 23.73 | 23.21 |
| Old River u/s Middle River bifurcation | 10 | 10.40 | 11.78 | 13.27 | 10.35 | 11.67 | 12.75 |
| | 50 | 12.05 | 13.65 | 13.28 | 12.00 | 13.56 | 13.00 |
| | 100 | 13.32 | 16.17 | 21.40 | 13.23 | 16.12 | 21.84 |
| | 200 | 14.67 | 17.85 | 21.68 | 14.61 | 17.77 | 21.63 |
| | 500 | 17.69 | 19.44 | 9.89 | 17.52 | 19.36 | 10.50 |
| Old River near d/s end of SJRUNET | 10 | 7.53 | 8.32 | 10.49 | 7.52 | 8.25 | 9.71 |
| | 50 | 8.86 | 9.18 | 3.61 | 8.85 | 9.16 | 3.50 |
| | 100 | 9.24 | 9.64 | 4.33 | 9.22 | 9.63 | 4.45 |
| | 200 | 9.58 | 9.90 | 3.34 | 9.57 | 9.89 | 3.34 |
| | 500 | 10.06 | 10.26 | 1.99 | 10.04 | 10.25 | 2.09 |
| Paradise Cut d/s Paradise Weir | 10 | 16.89 | 17.52 | 3.73 | 16.87 | 17.48 | 3.62 |
| | 50 | 18.94 | 19.81 | 4.59 | 18.91 | 19.77 | 4.55 |
| | 100 | 20.82 | 22.99 | 10.42 | 20.77 | 22.99 | 10.69 |
| | 200 | 22.56 | 25.74 | 14.10 | 22.52 | 25.73 | 14.25 |
| | 500 | 25.88 | 28.70 | 10.90 | 25.87 | 28.70 | 10.94 |
| Grand Line Canal Near d/s end of SJRUNET | 10 | 7.44 | 8.31 | 11.69 | 7.43 | 8.24 | 10.90 |
| | 50 | 8.86 | 9.17 | 3.50 | 8.85 | 9.15 | 3.39 |
| | 100 | 9.26 | 9.65 | 4.21 | 9.24 | 9.65 | 4.44 |
| | 200 | 9.59 | 9.89 | 3.13 | 9.58 | 9.88 | 3.13 |
| | 500 | 10.04 | 10.19 | 1.49 | 10.04 | 10.18 | 1.39 |

## TABLE VI-7 (CONT.)

| **SJRUNET Index Point** | **Return Period** | **Stage / % Change** | | | | | |
|---|---|---|---|---|---|---|---|
| | | ***Scenario 2*** | | | ***Scenario 3*** | | |
| | | **w/o levee strength.** *(ft)* | **w/ levee strength.** *(ft)* | **difference** % | **w/o levee strength.** *(ft)* | **w/ levee strength.** *(ft)* | **difference** % |
| *Middle River d/s Old River* | *10* | 10.40 | 11.78 | 13.27 | 10.35 | 11.67 | 12.75 |
| | *50* | 12.05 | 13.65 | 13.28 | 12.00 | 13.56 | 13.00 |
| | *100* | 13.32 | 16.17 | 21.40 | 13.23 | 16.12 | 21.84 |
| | *200* | 14.67 | 17.85 | 21.68 | 14.61 | 17.77 | 21.63 |
| | *500* | 17.69 | 19.44 | 9.89 | 17.52 | 19.36 | 10.50 |
| *Middle River near d/s end of SJRUNET* | *10* | 6.27 | 6.55 | 4.47 | 6.27 | 6.60 | 5.26 |
| | *50* | 7.06 | 6.65 | -5.81 | 7.17 | 6.71 | -6.42 |
| | *100* | 7.61 | 6.80 | -10.64 | 7.64 | 6.89 | -9.82 |
| | *200* | 7.90 | 6.96 | -11.90 | 7.93 | 7.13 | -10.09 |
| | *500* | 8.25 | 7.72 | -6.42 | 8.30 | 7.75 | -6.63 |

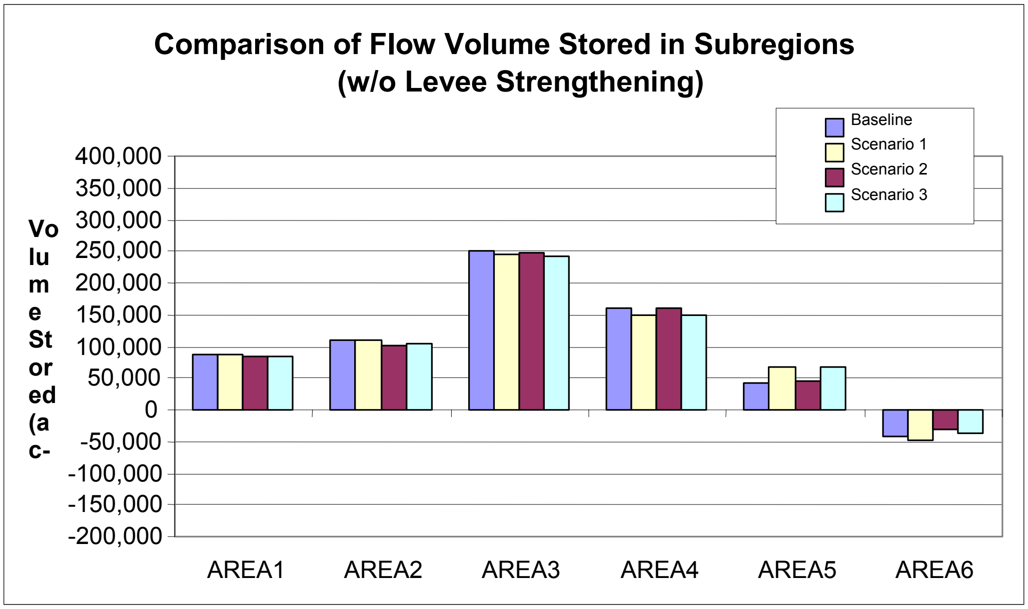
## Other Observed Effects

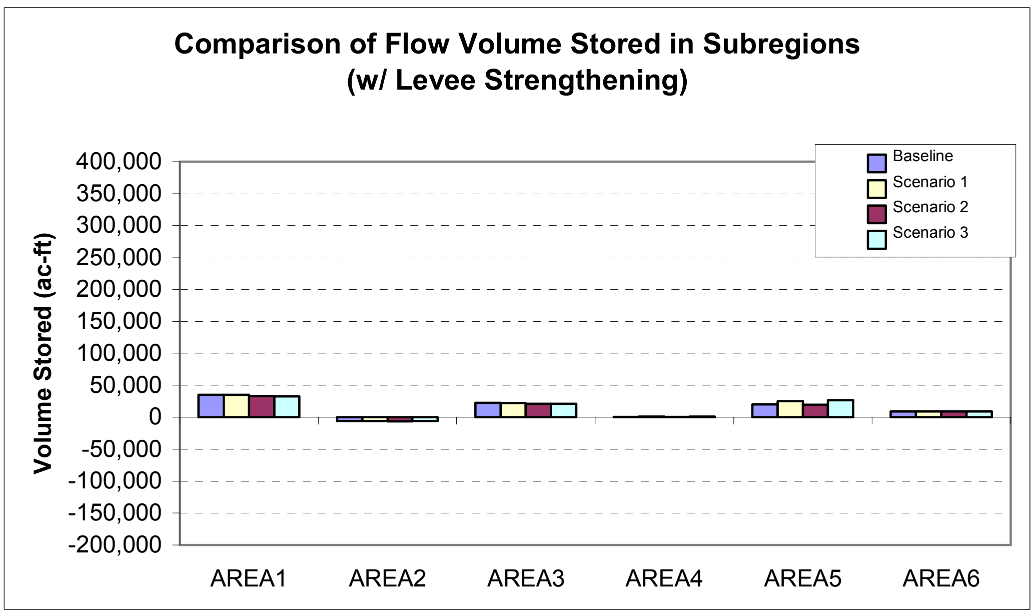
The modeling results can also be compared based on impacts to geographic subregions. The six subregions identified in the Lower San Joaquin study area are described in Table VI-8.

**TABLE VI-8**
**SUBREGIONS OF THE LOWER SAN JOAQUIN STUDY AREA**

| Subregion | Upstream Boundary | Downstream Boundary |
|---|---|---|
| *Area 1* | San Joaquin River below Stanislaus River | San Joaquin River above Paradise Cut Weir |
| *Area 2* | San Joaquin River below Paradise Cut Weir | San Joaquin River above Old River Bifurcation |
| *Area 3* | San Joaquin River below Old River Bifurcation | San Joaquin River near d/s end of SJRUNET |
| *Area 4* | Old River below San Joaquin River Bifurcation | Old River above Middle River Bifurcation |
| *Area 5* | Middle River below Old River Bifurcation | Middle River near d/s end of UNET model |
| *Area 6* | Paradise Cut below Paradise Cut Weir, and Old River below Middle River Bifurcation | Grant Line Canal near d/s end of SJRUNET, and Old River near d/s end of SJRUNET |

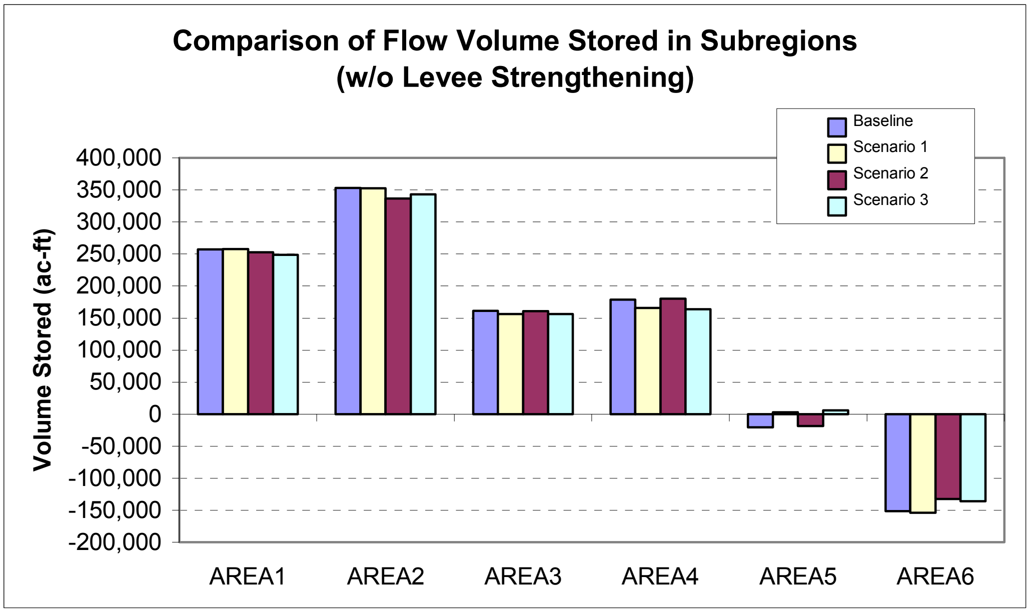
The purpose of comparing the storage in subregions is to illustrate the distribution of floodwaters in the Lower San Joaquin area on a large-scale basis to partially digest the large amount of simulated results have been generated through the study (see Appendices). The comparison also grossly assesses the nature of the flooding in a subregion; whether the floodings are largely contributed by river outflows from local levee breaks or from levee breaks in other subregions.
The volume stored in each subregion during the simulated period is the difference between the total channel inflows to the subregion minus the total channel outflows from the subregion. Note that the levee break points simulated in SJRUNET would allow flows in and out of the channel, depending upon the difference in concurrent stages in the channel and in the nearby storage area. Most of the subregions would have a positive storage during the storm event, indicating the floodings in nearby areas are largely contributed by local levee failures. These floodwaters could enter into channels in other subregions and if the amount were to be significant, the storage would be negative (e.g. Subregion 6, where the flooding of nearby areas could be contributed largely from levee failures in other regions).

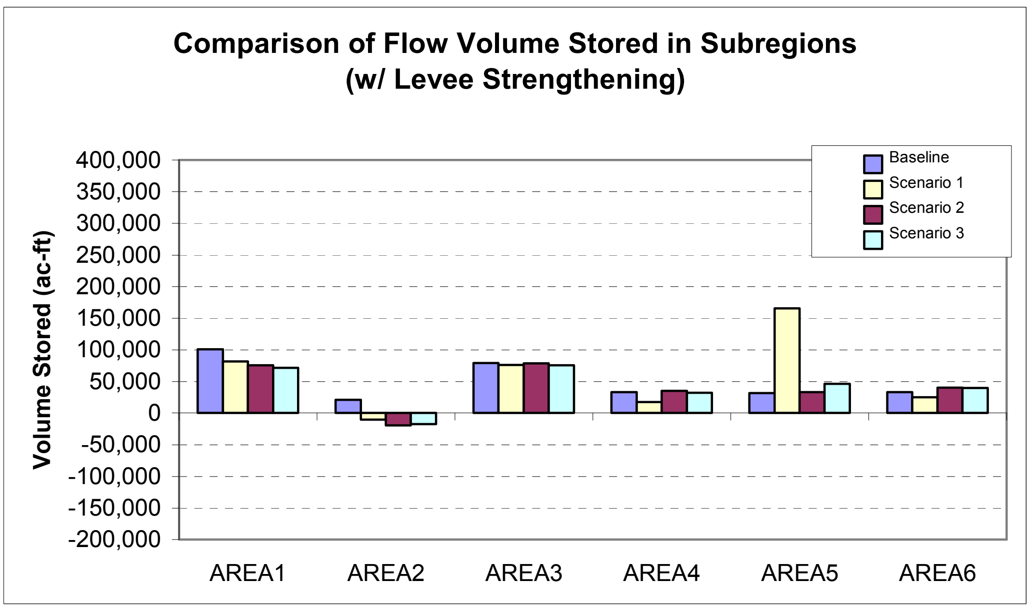



*Note: Volume calculation was based on the SJRUNET simulation period*

**FIGURE VI-5 VOLUME STORED IN LOWER SAN JOAQUIN MODEL SUBREGIONS 100-YEAR EVENT**




*Note: Volume calculation was based on the SJRUNET simulation period*

**FIGURE VI-6 VOLUME STORED IN LOWER SAN JOAQUIN MODEL SUBREGIONS 200-YEAR EVENT**

## CONCLUSIONS

The following conclusions can be made in relation to the evaluation of the Lower San Joaquin study area:

- Scenario 1 – Dredging/Sediment Removal in Middle River provided localized flood damage reduction benefits, but had little impact on the lower San Joaquin system as a whole.

Dredging a longer reach of Middle River did not result in a significant increase in flood benefits.

- Scenario 2 – Constriction Removal along Paradise Cut provided localized flood damage reduction benefits to neighboring lands, particularly Stuart Tract, but had little impact on the lower San Joaquin system as a whole. Removal of the constriction reduced river stage upstream from the constriction, which may reduce the risk of levee failure.
- Scenario 3 – Major Levee Realignment along the San Joaquin and Middle Rivers provided the greatest flood damage reduction benefits of the three scenarios evaluated. However, these benefits were generally limited to the areas immediately adjacent to the improvements, and did not result in significantly lower stage in other river reaches or waterways.
- The three scenarios demonstrated that the complex Lower San Joaquin study areas acts collectively like a “pool” of water, rather than a system of individual flood channels. This is a commonly observed feature of flat, delta distributary systems. The flood benefits of increasing channel flow or stage tend to be localized because effects are re-distributed throughout the system.
- The scenarios modeled on the distributaries (Paradise Cut, Old River, and Middle River) are characteristic of many measures to increase the flow capacity or decrease the stage. It is unlikely that other scenarios to increase the flow capacity or decrease the stage of San Joaquin distributaries would be more effective than those evaluated.
- Modification of the Paradise Cut Weir does not appear to have any flood damage reduction benefits because the weir is highly submerged during flood events. Weir modification may be necessary if other measures result in a significantly lower stage in the San Joaquin River than under current conditions.
- While scenarios to move more water through the lower San Joaquin and into the Delta were hydraulically ineffective, there may be an opportunity to redirect water out of the study area using existing CVP-SWP pumping facilities. The CVP and SWP pumping facilities in the south Delta have a total pumping capacity of about 10,000 cfs. These pumps were utilized during the 1997 flood event to pump flood flows
- Levee strengthening had a mixed impact on flood damages in the area. Little impact was observed to inflow to the study area, but outflow at the downstream model boundaries increased significantly. In addition to the downstream impacts, stages were higher throughout the Delta.
- DSM2 cannot simulate levee failure and hydrodynamics around bridges and other obstacles in the river, thus, the simulation results can only be used in scenario comparison. Inferences on absolute stages and flows during floods based on DSM2 simulation results are not appropriate.

The Comprehensive Study is tasked with developing comprehensive plans to improve the overall performance of the flood management systems in the Sacramento and San Joaquin River Basins. This involves the identification of measures that have an impact on the system as a whole, rather than developing measures that address specific, local flood issues. The three scenarios modeled in the Lower San Joaquin study area showed localized improvements, with negligible impacts to other waterways, including the San Joaquin River. The complex hydraulics of the Lower San

Joaquin and Delta were observed to re-distributed scenarios impacts, the system acting more as a "pool" than a group of individual flood channels. With the exception of the levee strengthening component, no hydraulic impacts to the Delta were observed as a result of the three scenarios evaluated.

# CHAPTER VII

# REFERENCES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Appendix E – Measure Screening Report

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